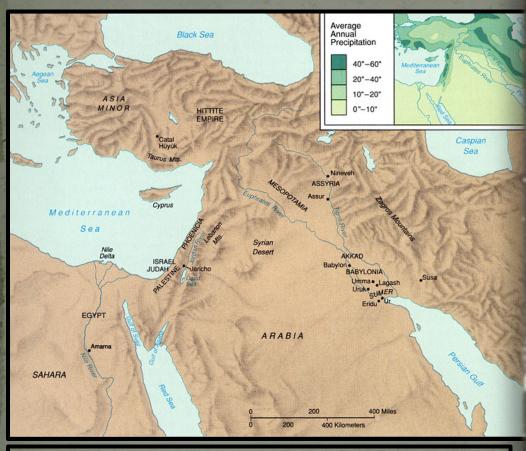






Babylonian Astronomy



Mesopotamia = "land of two rivers" land between the rivers Euphrates & Tigris

Babylonian Astronomy

Two distinct periods of flowering:

Old Babylonian astronomy:
 during and after
 First Babylonian dynasty (Hammurabi)

1830-1531 BCE

New Babylonian/Chaldean astronomy:

Neo-Babylonian (Nebuchadnezzar) Medo-Persian

dnezzar) 626-539 BCE 539-331 BCE 335-141 BCE

Parthian

Seleucid

129 BCE-224 AD

Babylonian Astronomy

timeline Babylonian astronomy

Evans 1998



| DATE | ASTRONOMY | GENERAL HISTORY |
|-----------------------|------------------------------|-------------------------|
| Old Babylonian Period | | Reign of Hammurapi |
| 1700 BC | | |
| 1600 | Venus observations | Enuma Elish |
| Kassite Dynasty | | |
| 1500 | | |
| 1400 | | |
| | Enuma Anu Entil | |
| 1300 | | |
| 1200 | | |
| Six Dynastics | | |
| 1100 | Oldest rectangular astrolabe | |
| 1000 | | |
| 900 | | |
| 800 | | |
| .,,,, | Eclipse records | Reign of Nabonassar |
| 700 Assyrian Rule | | |
| College Helds | MUL.APIN | Reign of Ashurbanipal |
| 600 Chaldacan Dynasty | Oldest astronomical diaries | |
| Persian Rule | *** | |
| 500 | Equal-sign zodiac | |
| | Regularization of calendar | |
| 400 | | |
| Seleucid Dynasty | | Alexander takes Babylon |
| 300 | Planetary theory | |
| | a rose our j | |
| 200 BC | | |
| 100 Parthian Rule | | 111 |
| 100 Parthian Rule | | , |

Babylonian Astronomy

Babylonian Astronomers:

- most consistent, systematic and thorough astronomical observers of antiquity
- ☐ First to recognize periodicity astronomical phenomena (e.g. eclipses!), and apply mathematical techniques for predictions
- Systematically observed and recorded the heavens:
 - Records spanning many centuries (> millennium)
 - Archives of cuneiform tablets
 - Famous Examples:

Enuma Anu Enlil

68-70 tablets tablet 63:

Kassite period (1650-1150) Venus tablet of Ammisaduga

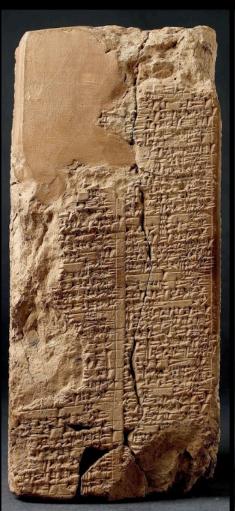
700 BCE

oldest copy: 686 BCE

MUL.APIN

Astronomical Texts



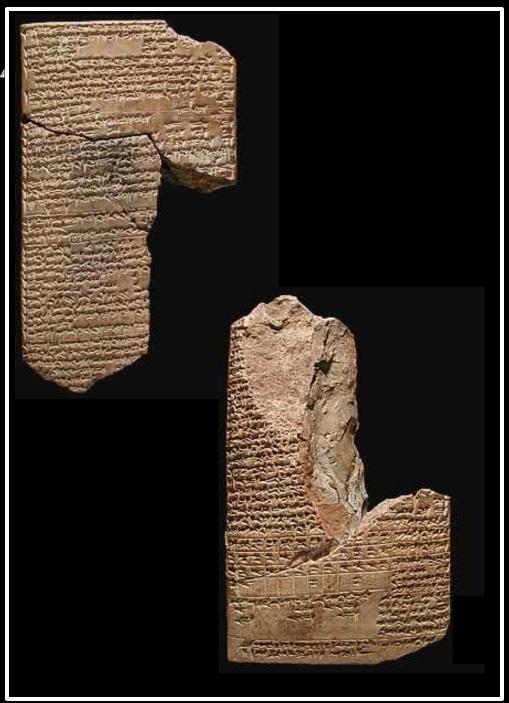




ENUMA ANU ENLIL

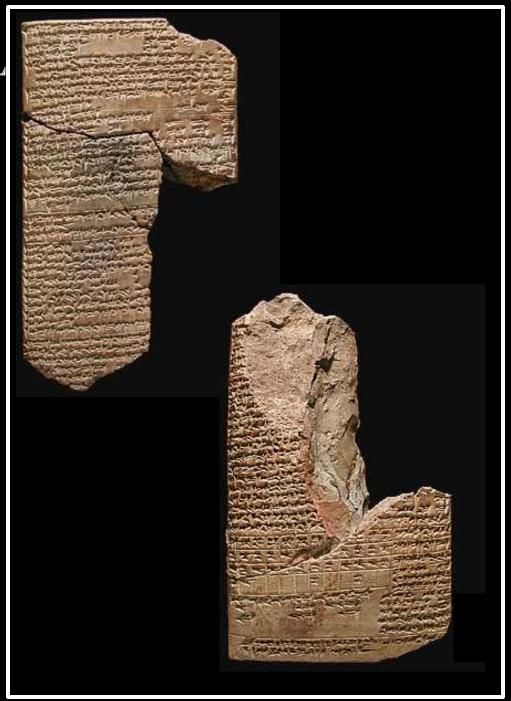
Old text, probably Kassite period (1595-1157 BCE)

- A major series of 68 or 70 tablets
- dealing with Babylonian astrology.
- bulk is a substantial collection of omens, estimated to number between 6500 and 7000,
- interpreting a wide variety of celestial and atmospheric phenomena in terms relevant to the king and state



ENUMA ANU ENLIL

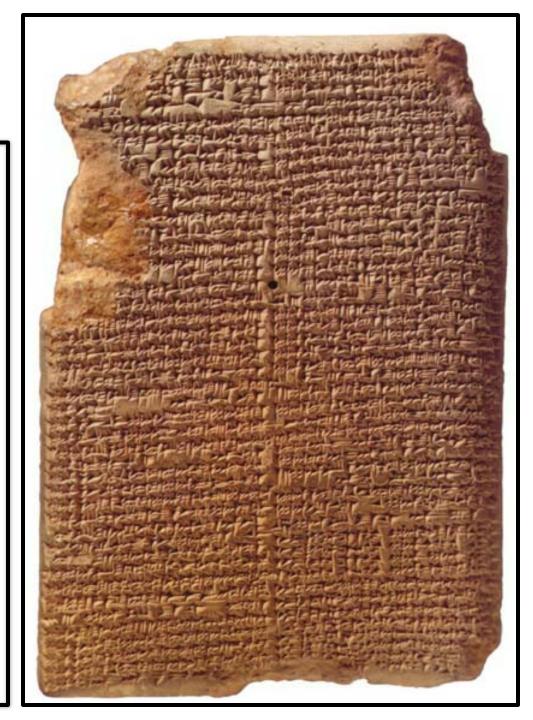
- **2.** If with it a cloudbank lies on the right of the sun: the trade in barley and straw will expand.
- 3. If with it a cloudbank lies to the left of the sun: misfortune
- 4. If with it a cloudbank lies in front of the sun: the king of Elam [will die]
- 5. If with it a cloudbank lies behind the sun: the king of the Gutians [will die]
- 6. If in Pit babi the sun is surrounded by a halo in the morning: there will be a severe heat in the country and the Lamashtu-demon will attack the country.
- 7. If with it a cloudbank lies to the right of the sun: the king of Eshnunna will die.
- 8. If with it a cloudbank lies to the left of the sun: the king of Subartu will die and his dynasty will come to an end.
- 9. If with it a cloudbank lies in front of the sun: the rains from heaven (and) the floods from the depths will dry up.
- 10. If with it a cloudbank lies behind the sun: the harvest of the land will not be brought in.



MUL.APIN

Around 700 BCE, after king Nabonassar

- summary of astronomical knowledge (Neugebauer)
- Parapegma (Evans)
- Catalogue of stars & constellations
- Schemes heliacal risings/settings planets
- Measurements lengths daylight
- 66 stars





- Most Chaldean astronomers strictly concerned with ephemerides, not with theoretical models
- Predictive planetary models empirical, usually sophisticated arithmetical/numerical schemes
- ☐ Models do not involve geometry & cosmology (that's the Greeks!)
- Discovery (lunar & solar) eclipse cycles & Saros period

Babylonian Astronomy



Lasting Astronomical Influence:

Constellation Names

DZodiac

Degree - unit angle

Sexagesimal number system:

circle: 360 degrees

degree: 60 minutes

place value number system (crucial for Greek science!)

DEclipse Observations & Periods

Synodic, Siderial, Draconic, Anomalistic months

[] and ...

Magi: Chaldean Astronomers



Babylonian Astronomy

Transmission:

- Transfer of Babylonian astronomical knowledge essential for Hellenistic astronomy
- Alexander the Great:



orders translation astronomical records, under supervision Callisthenes of Olynthus,

to be sent to his uncle Aristoteles

Direct Contacts:
e.g. Hipparchus



Timeline & Overview

Greek Cosmology

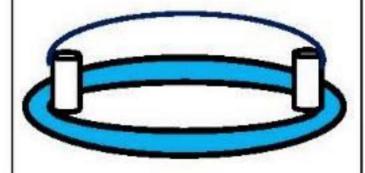
8th Century BCE: mythical cosmology

8e eeuw v.Chr.

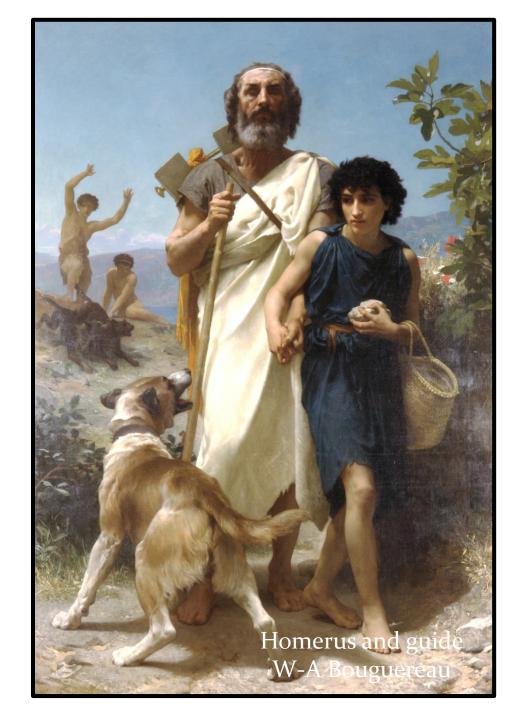
Mythische cosmologie

Homerus & Hesiodus

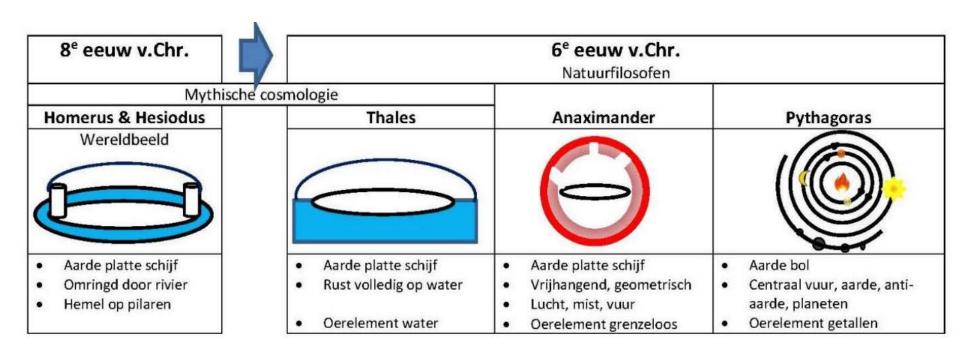
Wereldbeeld



- Aarde platte schijf
- Omringd door rivier
- Hemel op pilaren



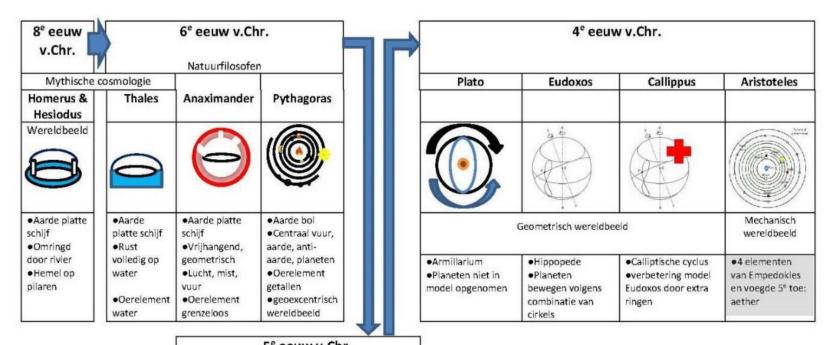
6th Century BCE: Pre-Socratic Ionian Natural Philosophers



5th Century BCE: Pre-Socratic Natural Philosophers

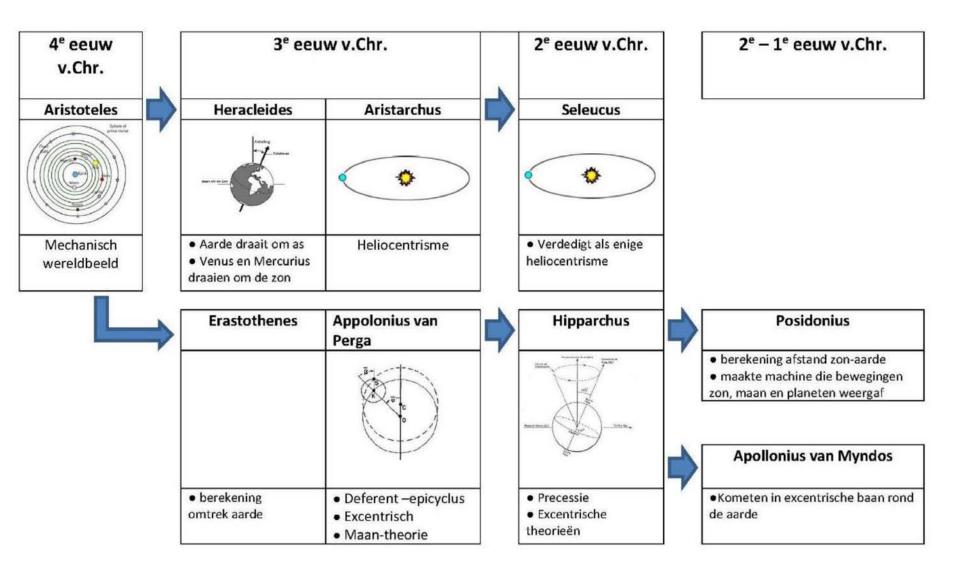
| 8e eeuw v.Chr. | | 6 ^e eeuw v.Chr. Natuurfilosofen | | | 5 ^e eeuw v.Chr. | | |
|--|---|---|--|--|---|---|--|
| Mythische Homerus & Hesiodus | cosmologie Thales | Anaximander | Pythagoras | Anaxagoras | Empedokles | Leukippos & Demokritos | |
| Wereldbeeld | | | | Geen oerelementen Alles bevat een deel van al het andere Hemellichamen <u>niet</u> goddelijk | •4 oerelementen: aarde, lucht, vuur, water •2 eigenschappen: warm, koud •Alles bestaat uit | Alles bestaat uit atomen Atomen zijn ondeelbaar en onveranderlijk, maar verschillen in vorm | |
| Aarde platte schijf Omringd door rivier Hemel op pilaren | Aarde platte schijf Rust volledig op water Oerelement water | Aarde platte schijf Vrijhangend, geometrisch Lucht, mist, vuur Oerelement grenzeloos | Aarde bol Centraal vuur, aarde, anti-aarde, planeten Oerelement getallen | | verhouding van elementen met de 2 eigenschappen (4²= 16 mogelijkheden) | en grootte | |

4th Century BCE: from Plato to Aristoteles



| Anaxagoras | Empedokles | Leukippos & Demokritos • Alles bestaat uit atomen • Atomen zijn ondeelbaar en onveranderlijk, maar verschillen in vorm en grootte | |
|--|--|--|--|
| ●Geen oerelementen ●Alles bevat een deel van al het andere ●Hemellichamen niet goddelijk | •4 oerelementen: aarde, lucht, vuur, water •2 eigenschappen: warm, koud •Alles bestaat uit verhouding van elementen met de 2 eigenschappen | | |

3rd Century BCE – 1st Century AD: the Hellenistic Scientific Revolution



Ionia

Natural Philosophers

Ionia, 6th century B.C.

Phase transition in human history: the mythical world obsolete

... the Ionian coast, 6th century B.C., regularities and symmetries in nature recognized as keys to the cosmos ...





Mathematics as natural language of cosmos

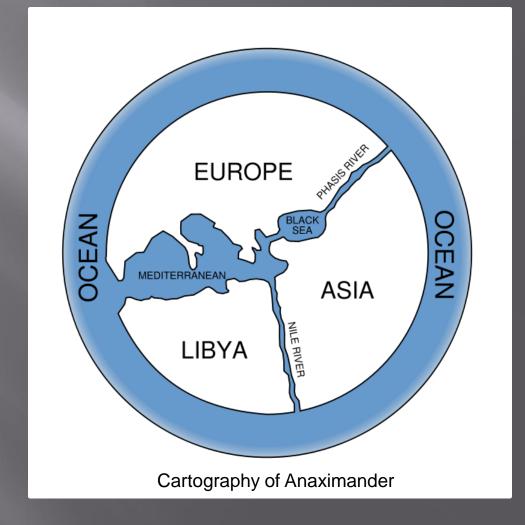
→ Physical cosmos modelled after *ideal form*, encrypted in concepts of *geometry*

... Anaximander of Miletus:
Pythagoras of Samos:
Plato:

the Apeiron music of spheres Platonic solids

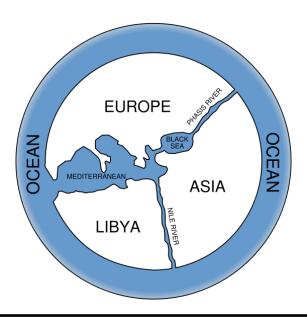


the First Cosmologist (Miletus, 610-546 BCE)





the First Cosmologist (Miletus, 610-546 BCE)



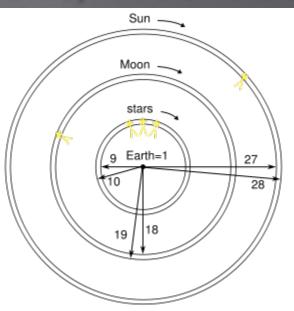
Cosmology of Anaximander:

- Earth floats free without falling
- Karl Popper:

"one of the most boldest, most revolutionary, and most portentous ideas in the whole history of human thinking"



founder scientific Astronomy and Cosmology (Miletus, 610-546 BCE)

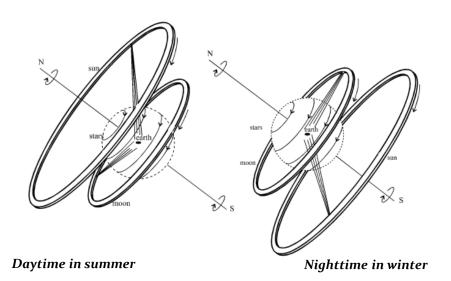


Cosmology Anaximander

- heavenly sphere is a ring of fire
- invisible, surrounded by fog
- Heavenly bodies part of ring, visible through openings through fog.
- ring for the Moon
- ring for the Sun



founder scientific Astronomy and Cosmology (Miletus, 610-546 BCE)



Cosmology Anaximander

- Ring model could not explain all observations
- Anaximander preferred symmetry & number 3
- diameter Sun ring = 27 x diameter Earth
- diameter Moon ring = 18 x diameter Earth
- diameter stellar ring = 9 x diameter Earth



founder scientific Astronomy and Cosmology (Miletus, 610-546 BCE)

"The Apeiron, from which the elements [are formed], is something that is different"

The idea of Apeiron, the "infinite" or "limitless" out of which the world emerged, is suggested to be close to our current idea of vacuum energy

Classical Greek Cosmology

Plato & Aristoteles

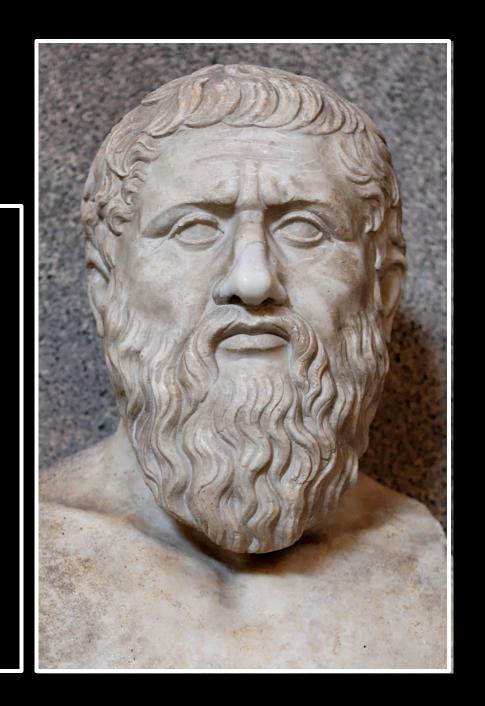
Plato

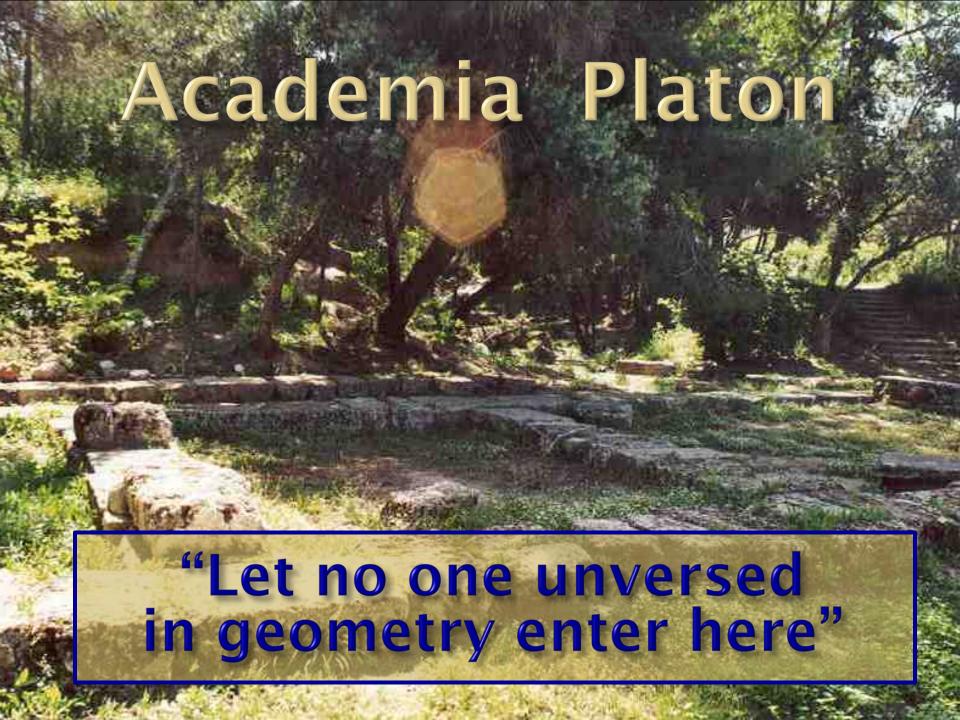
(Athens, 428-348 BCE)

Geometry as organizing principle of the world

Founded Academy, Athens

- Philosophy
- Mathematics
- Philosophical Dialogues





Branco comin quotalio mi noo curfuf folon warre lo obfaculor offultionila & reponente obfermente ou perro offer mont mais rate Quantin longs excelle deminent from que aplanof or fubr que potur fin Practical or many ! Pfricail & large global of a rofter governing of poble comings in para qua expurera ou incustitorion Kalent experientes o brare Solair curlina riniqua obfar alia Molla fireriore our farmore conere it di promot factor lever fly derenveno operat lucor roger at ai ober the five whenir refuler - Sollon is & lucoror ourse septerily fibration obfit huns spri mentural cat plenia com Fromer de filmul abobil some file occubent phonomo & confiplar file as direct is level rang Holl of ob umbranes Luigh and oramore afole or frant sincurror working iry objectar necrain omily infibr fie no omi quevo come boco ominous lune folif obumbrano virumer wor one plone proving lune lung labor my obfarano portra gat arcularos noma chiquesso a fo weacon wife rans. Opper fol fubipte libra movement fignators and movies open forms vollenor and warm for morning vollerang at man from at maglorio - Ar a tuna wafforen hyperouf var unung moving vous poporte let frupig orbot opposed it planet store alla folderer si fold qua lung of der must animo poficof apur fil fo ma ou reda poficione un una granduof orbef via la line form our plane for bile infigurar orn summer of unbost rave linear Krifuna parf feuntonf pound carealis casabyhasen appellat. Ima is focusf pour fifti urrfu maiore orbe anabibason Quare promur folis clumpfier our of ful studen appendicule vol financing uppers primuffile fac hif ex con curfu corporits obtact fo some until nom a obflatill angufti ucoenor obficed marrier luna lucing folif a not arer munor lock mules masore observant

atur of her pur soforting for our or her in the her diener in land luci planting on defer a use out of the soft of

observed in privacy wegut in coulost nort money Sin ary pensiculi comul

cot factuloru fasplanal god inivalle ora Larra porro usgoro doclina.

murf funce you got monoluped wings gorle in Junerapula raid

I urrgar nulla observano fiere?

aglaboth urray Profession a game of unit A L'Alers a Bete moure himselverof were for offe poster of sale different morne ga article A.B. viamorus of out THE STHEAM INDING STON W. T. E. PARING. por o hoco fine deduranone & z.e. aduptit above & wife padus in writing lacor and us pquali q efer pigor e nec rou cacumina cungent umqua ut cungent fo muce and a mafer dubumnone I.A. foor workyam woffigion che liners formant exercence pummentum lever port of h Lange guopluf er ofcent offigune openant . Cryp fine chylindrosof fou calashorde or comingar necess off in mules filly que supra nos immenobum y nocho in undonto anoto has aux illa alsalanbris obrothe & ob Pantibut So ratione how non haber . Oportor grear temp marorem offe illustranie globishif que illuminamur A majorfiliar and a hour population magnitudent in 2 00 minut were green quet elluftranor in 11-P. urrage un globofa 11-P. arcul umbra que 11-P. conul nature inmovie cone definent inacurren inderner franz Z TI & O. P. gadief porred infundine Komungembe for mouse apus norum C. qual for exceden qua P. Il diame grof minor of the diamorro Z. O. Porer rage umby forat consider of w. Quia ignur hyppe cut were oper of forber do frontier my minelly fole & lary millow tingeness of togethe parties pomorim offe qua luna muleogo folom alexorom efferquam luna fir apperer similare to your milit office Queppe radesfold 2. 11 Rosen O.P. inguf same to were bushing up the & devera long one dlumeran - Torra a Son relience fold arcifluence fo lumino ambia office a hamore for larunders manguftra pure ta. & ufor adfinon ulumi anguf trapii arromuna. Qua ci mador tr . nother na oramerro a in & folo of lanf us que popa luce integrat enquafole femp murumrup offir minor qua ara obfiftorus fibina intomobrat calit. Porro ainen ander tobi pigo o fols ir por a lung poficio cuente cue p punda meditoria cyanfini diametra lanon for fol maquitorio lumi man fra werger ut come mafe irone writer mille parmy objectione?

france à come que also me no con fai il se ma preser ou me les essels interes proponente desperante en come en contra la media de la completa de proposition de la come de la co

obliquessorify orbit expositions viner frant fuperior of trust humber of falls. Dorn on should distribute our unplify point extraordinate or or orbit of the more or per extraordinate of the magnifer of abhoring else instantance observate. Darfour surfaper so place extraordinate observate of the orbit of

 with A. Manifortive of union of the k. A. our of k. M. N. A. informan

quiet offiguars calarin no sain hane species enwars estated of the union unimmensus. Na cit

for major k. A. viamorrof o. H. diamono, pro to same M. k. M. yazur qua o. A. M. iniminsum

por roch lance to quoplus crescent offiguars opecuars. Co go sine unique

divindressos son calarhoidos or a contagas nocoste of a unimper police

que supra nos imminebum encoste na unique noche has aurilla aliambers.

obiacht & ob frantibus So varione hoc non haber. Oporter secur some

alluftratur in 11-P. urrage and globofa 11-P. circuli umbya que 11-P. considerary in 11-P. urrage and globofa 11-P. circuli umbya que 11-P. considerary in 1

si devera lenage omia dimensamo. Lorra a dismorra
folat arciofluence fo lumno ambra officer a diamorra
fui launudino manguftia, puol tai. & usq. adfinom
ulumii anguftiarii accomiera. Qua oi meedorro
noo turna, oramerro a ina & folo anfranti ur que, pha

marorem offe illustranie globishif que illuminamur

Plato's Cosmic Scheme:

boure tii privag argultii vailost rivost monur. Sii ave penoudii comul ort lactul oru-les plumal goc invalla von Lavos porro ingoro doclina.

Demiurge, divine craftsman, is a mathematician:

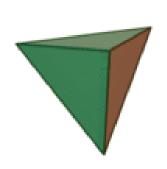
[Universe constructed according to geometric principles

mois deploser urpina for lain afformed clumored AB at a llumored F.A how qualia fire

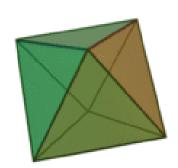
worger ut corner mafe if one wohre multi parmer obfermone?

the Five Platonic solids

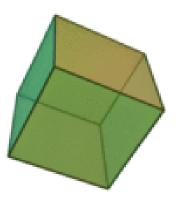
- there are only five convex regular polyhedra!
- Plato identified them with the cosmos and its constituents



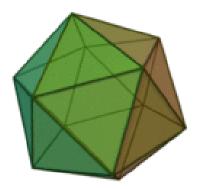
Tetrahedron: fíre



Octahedron:



Cube: earth



Icosahedron:

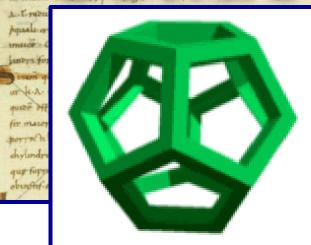
brancho comuni quel also rasi ne con les en su la comunicación de la c

Dodecahedron ← Quintessence

of which the Cosmos itself is made:

"the stuff for embroidering
the constellations on the heavens"

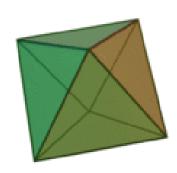




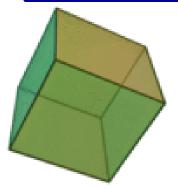




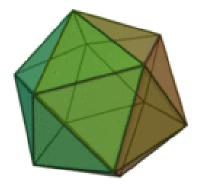
Tetrahedron: fíre



Octahedron: air



Cube: earth



Icosahedron: water

Aristoteles

(Chalcidice-Athens, 384-322 BCE)

- "Aristotle was the first genuine scientist in history ... every scientist is in his debt"

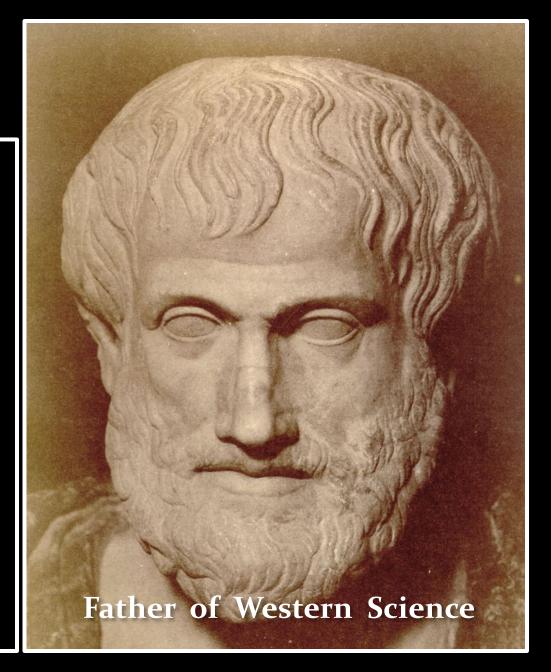
Physics, Metaphysics, Astronomy,
Poetry, Theater, Music,
Logic, Rhetoric, Ethics,
Politics, Government,
Geology, Biology, Zoology

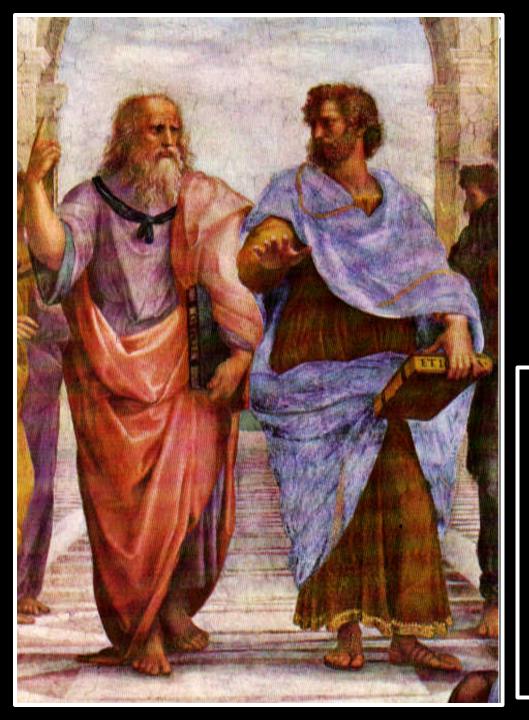
- Student Plato
- teacher Alexander the Great
- literary style:

"River of Gold" (Cicero)

- founded Lyceum, Athens
- Dominant influence for over 1800 years

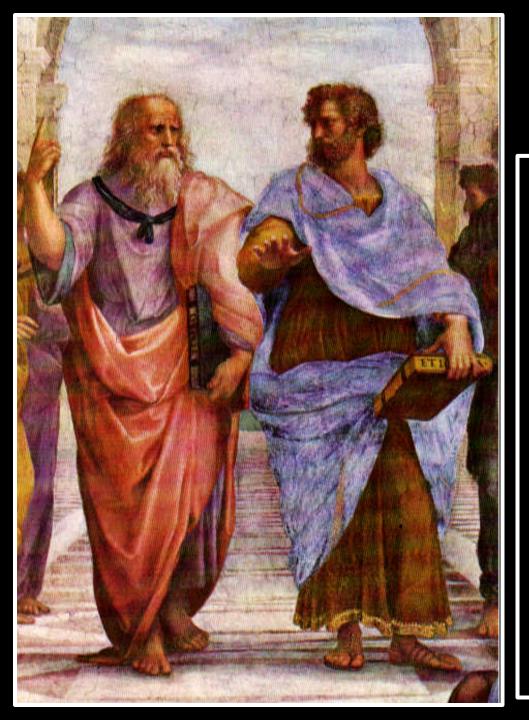
both in Christian philosophy & theology and in Muslim intellectual history





I saw the Master there of those who know, Amid the philosophic family, By all admired, and by all reverenced; There Plato too I saw, and Socrates, Who stood beside him closer than the rest.

Dante, Divina Commedia (1st level hell)

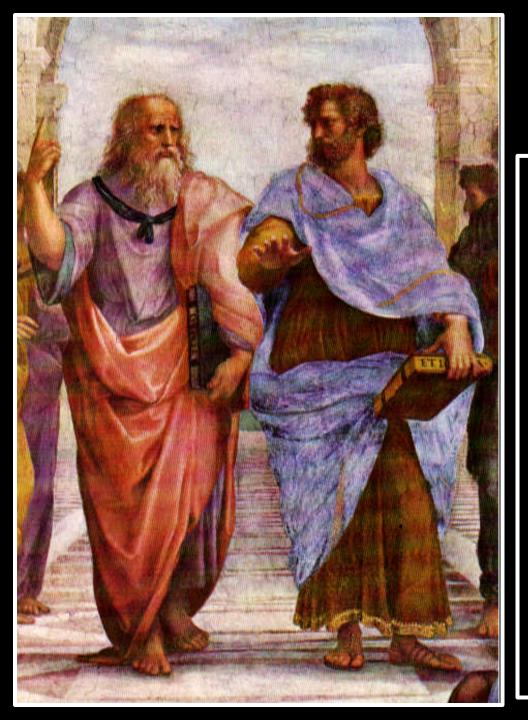


- Aristotle's cosmological work
- the most influential treatise of its kind in the history of humanity.

It was accepted for more that 18 centuries from its inception (around 350 B.C.) until the works of Copernicus in the early 1500s.

Key aspects of Aristotle's Cosmology:

- 1) Earth is at the centre of the Universe
- 2) the Universe is finite
- 3) the Universe is eternal and unchanged
- 4) the motion of the heavenly bodies are uniform and circular



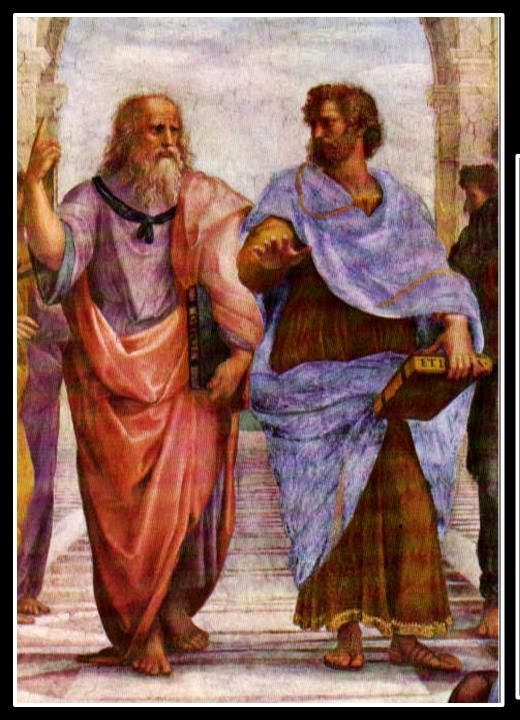
Four causes

Aristotle suggested that the reason for anything coming about can be attributed to four different types of simultaneously active causal factors:

- 1) **Material cause** the material out of which something is composed.
- **2) Formal cause** its form, i.e., the arrangement of that matter.
- 3) Efficient cause "the primary source", or that from which the change under consideration proceeds.

 This is akin to the modern concept
 - of cause.
- 4) Final cause

 its purpose, or that for the sake of which a thing exists or is done. This covers modern ideas of motivating causes, such as volition, need, desire, ethics, or spiritual beliefs.



• Elements - composition

4 elements (Empedokles)

1) Earth cold and dry - mod

- modern idea solid.

2) Water

cold and wet

- modern idea liquid

3) Air

hot and wet

- modern idea of a gas.

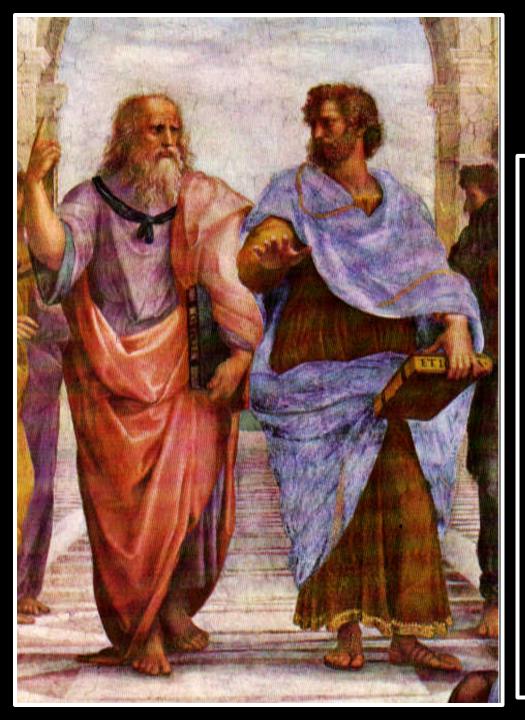
4) **Fire** hot and dry

- modern ideas of plasma

in addition, a 5th element

5) Aether

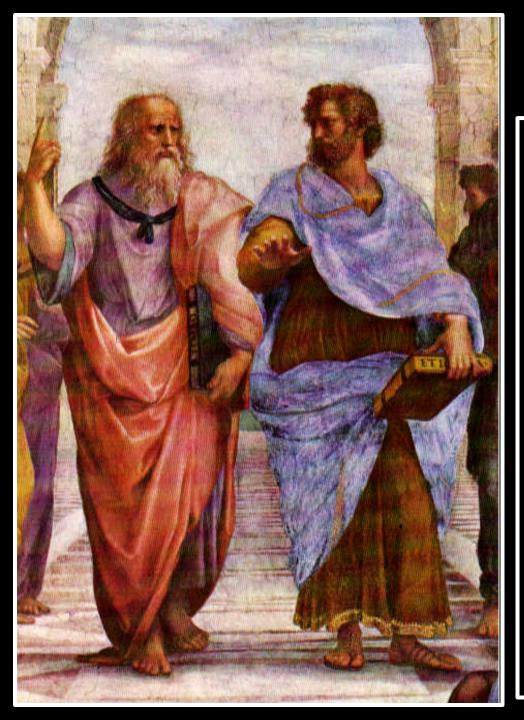
divine substance making up the spheres and heavenly bodies (stars and planets)



Movement of bodies

- all bodies, by their very nature, have a natural way of moving.
- Movement is *not*, he states, the result of the influence of one body on another
- Some bodies naturally move in straight lines
 - others naturally stay put.
 - Yet another natural movement: the circular motion.
- Since to each motion there must correspond a substance, there ought to be some things that naturally move in circles:

the heavenly bodies (made of a more exalted and perfect substance than all earthly objects).



• Aristotle's Cosmos

• Aristotle's Cosmos made of

a central earth (which he accepted as spherical)

surrounded by

- the moon,
- the sun
- stars all moving in circles around it.

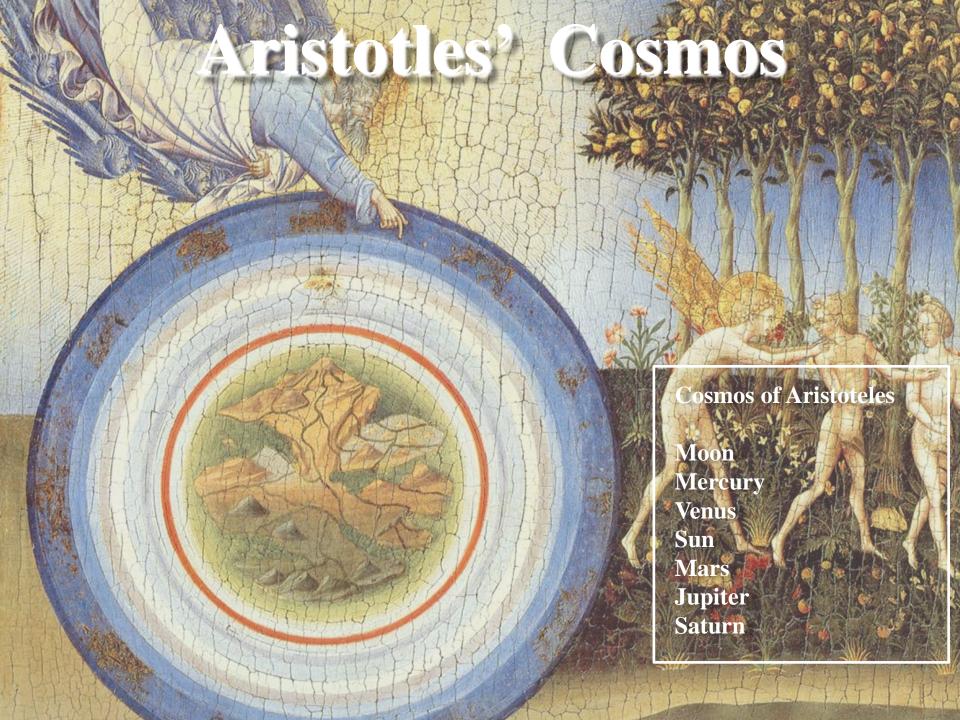
This conglomerate he called ``the world".

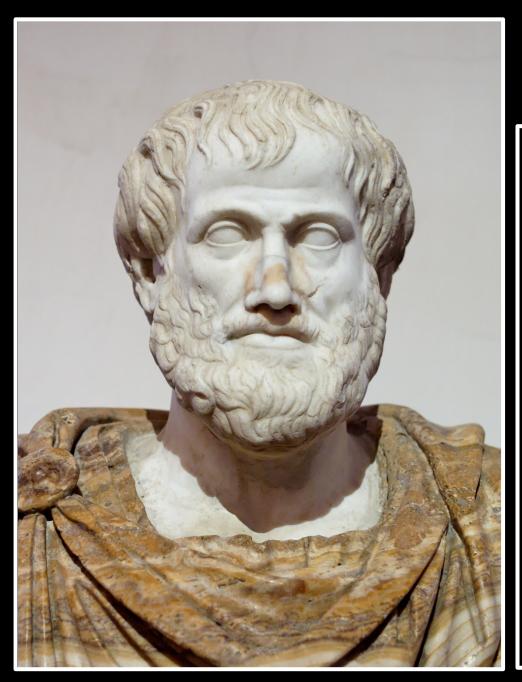
• Note the strange idea that all celestial bodies are perfect, yet they must circle the imperfect Earth.

The initial motion of these spheres was caused by the action of a ``prime mover" which (who?) acts on the outermost sphere of the fixed stars;

the motion then trickles down to the other spheres through a dragging force.

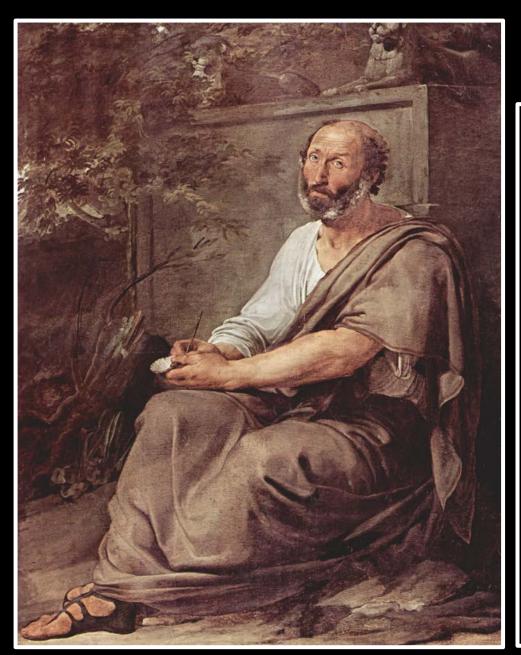
- Heavens consisted of a complex system of 55 spheres!
 - could explain and predict the motions of stars and planets
 - a real scientific theory





• Aristotle's cosmology

- this world is unique.
- the argument goes as follows:
 - earth (the substance) moves naturally to the center
 - if the world is not unique there ought to be at least two centers
 - but then, how can earth know to which of the two centers to go?
 - since ``earthy" objects have no trouble deciding how to move, there can only be one center (the Earth) circled endlessly by all heavenly bodies.
- Note:
 - this cosmological tenet turned out to be completely wrong with the discovery of the moons of Jupiter



• Existence

- the world did not come into being at one time
- The world has existed, unchanged for all eternity
 - it had to be that way since it was ``perfect";
 - the universe is in a kind of ``steady state scenario".
- Still, since he believed that the sphere was the most perfect of the geometrical shapes,
- the universe did have a center (the Earth)
- and its ``material" part had an edge,
- which was ``gradual"
 - starting in the lunar and
 - ending in the fixed star sphere.
- Beyond the sphere of the stars the universe continued into the spiritual realm where material things cannot be
- This is in direct conflict with the Biblical description of creation, and an enormous amount of effort was spent by the medieval philosophers in trying to reconcile these views.

