

A BRIEF HISTORY OF SCIENCE

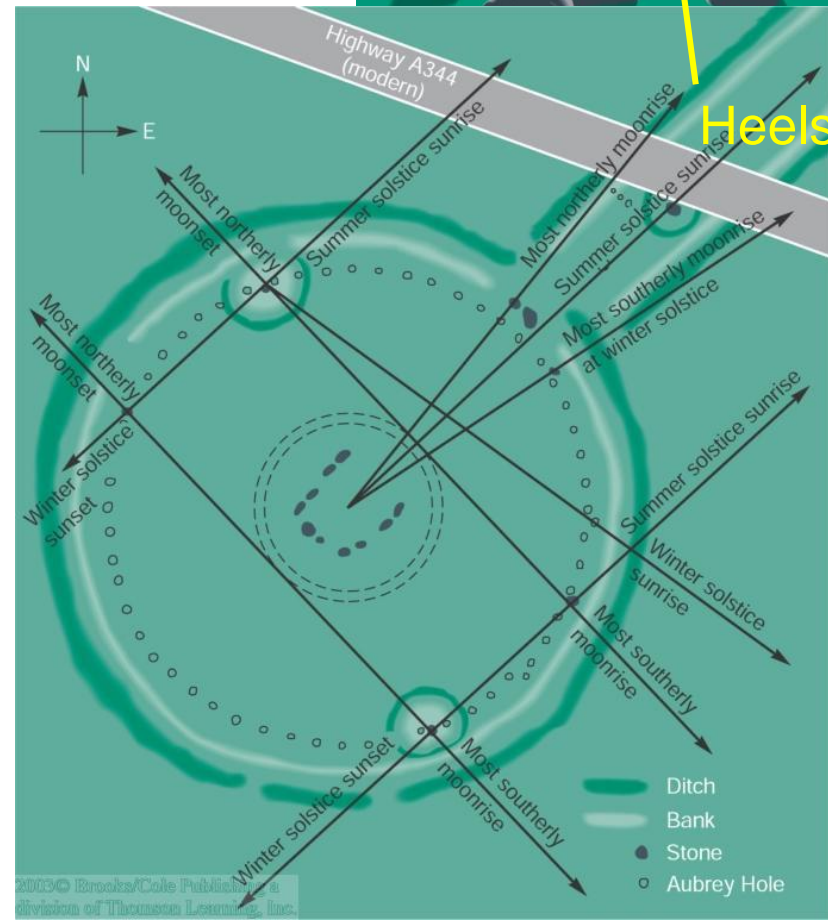
Astronomy - the first science

Questions are the foundation of science

- Started OUR year with two BIG questions
 - 1. Where am I?
 - 2. What time is it?
- We are not the first ones to ask these questions, nor will we be the last
- Science was first called “natural philosophy”

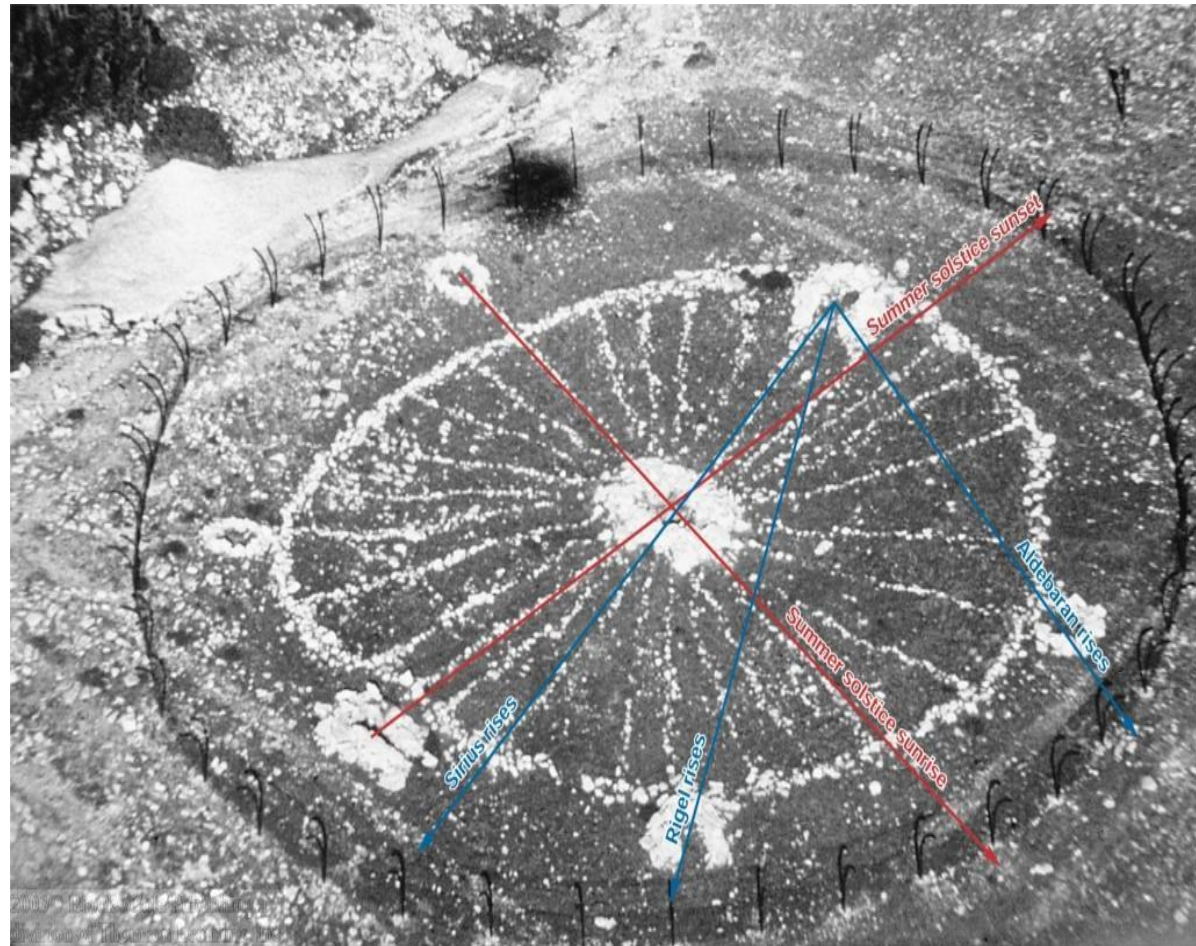
Archaeoastronomy

- We have evidence of early civilizations asking these questions
- Stonehenge
 - Constructed ~3000 -1800 BC
 - specific markings align with locations of sunset, sunrise, moon set and moon rise at the summer and winter solstices
 - Sun rises behind heelstone on summer solstice
 - Probably used as a calendar



Archaeoastronomy (2)

- Big Horn Medicine Wheel Wyoming
- Arrangement of stones and cairns (doughnut shape piles) – large enough to hold a sitting human
 - 1 center + 6 outside of circle of wheel
 - 28 spokes of the wheel
- indicate where Sun will rise or set on solstice
 - Help determine when to host ceremonial festivals



Evidence of studying the stars in days of the week

English

- Sunday
- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday

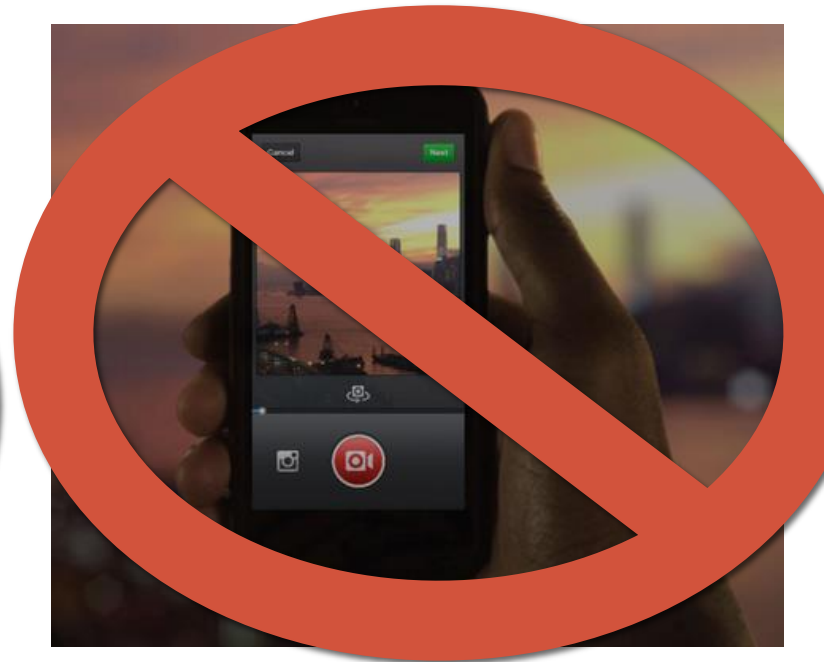
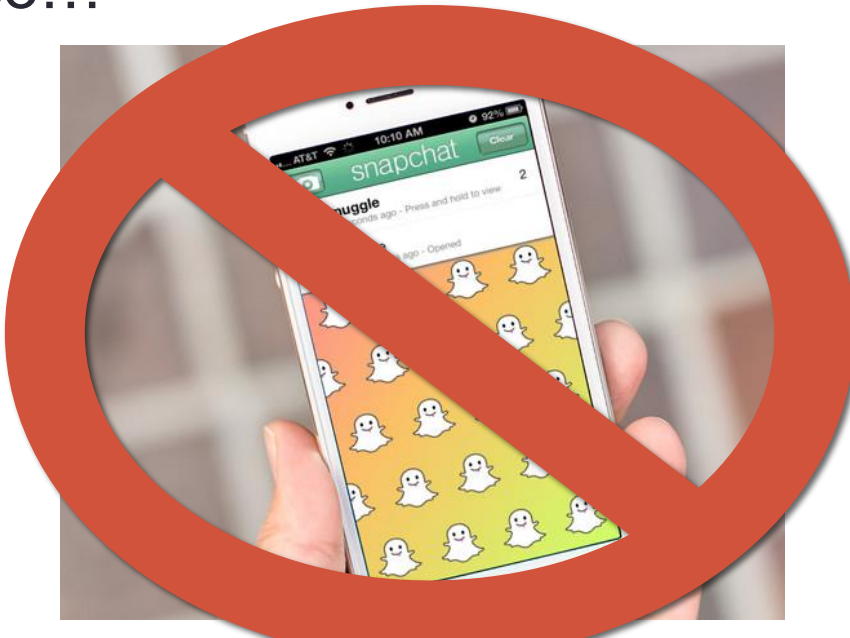
Spanish

- D_____
- L_____
- M_____
- M_____
- J_____
- V_____
- S_____

Why? Spanish is derived from Latin – language of the educated

Why did we study the stars?

- Presumed to understand, predict and influence people and events
- Civilizations all around the world at different times
 - Babylonians (~1600 B.C.) recorded position of planets, times of eclipse; early Chinese civilizations
- Also...











Ancient Greek Astronomers

- First preserved written documents on astronomy
- Tried to understand in mathematical models
 - Not physical structures
- Models were constructed on “obvious” and “unquestionable” principles
 - 1. Earth at the center of the universe
 - 2. Celestial “heavenly” bodies described by perfect shape
 - Circles and spheres
 - A shape with no beginning and no end
 - Represented harmony, unity, infinity
 - Infinite lines of symmetry
 - Impossible to create perfectly round circle

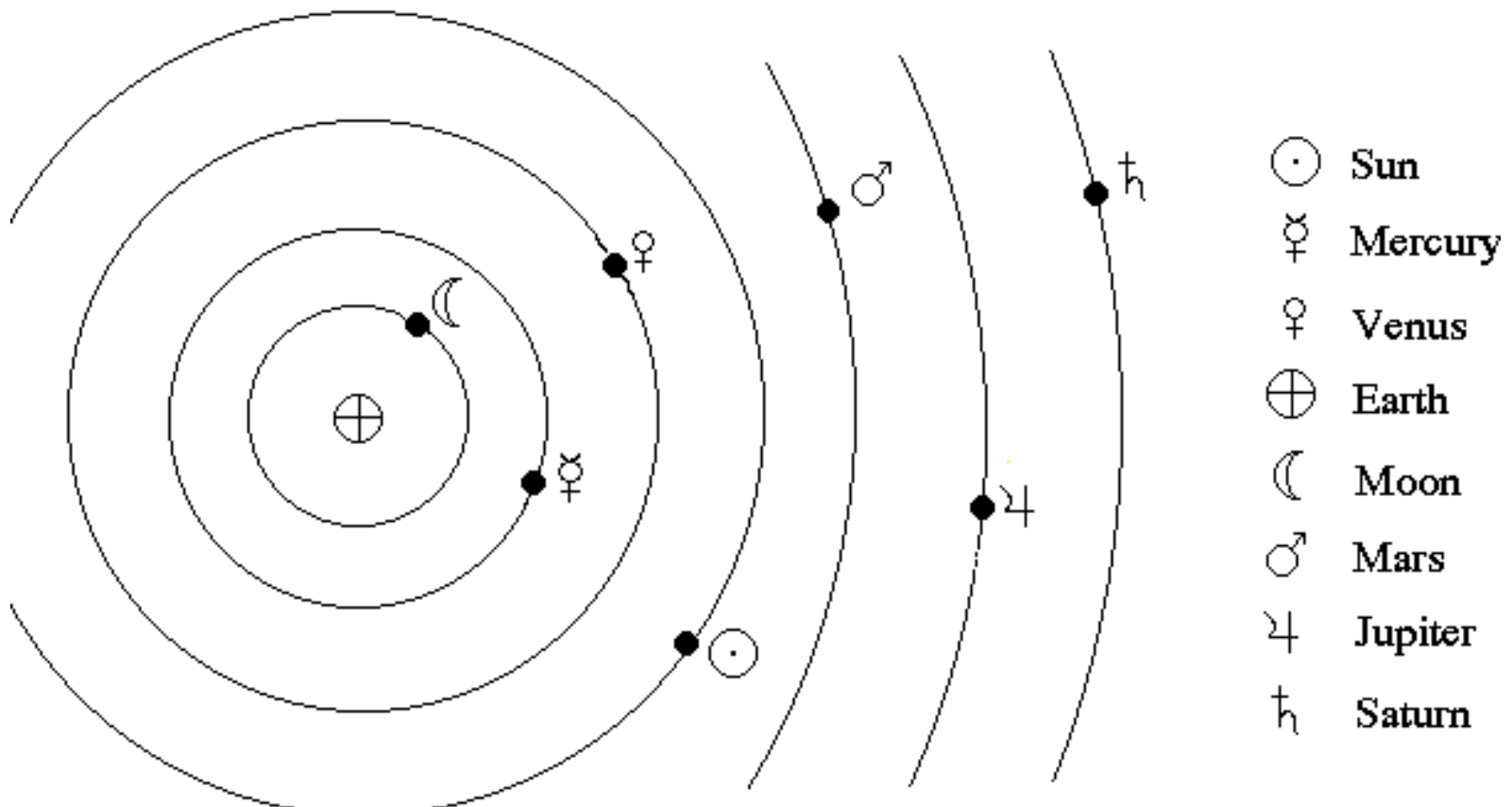
Ancient Greek Astronomers(2)

- Aristotle and Plato (~400 B.C.)
 - Universe split into 2 parts
 - Imperfect, changeable Earth and consisted of four elements
 - Perfect heavens consisted of a fifth element: ether
 - Why?
- Eratosthenes
 - Concluded Earth was a sphere
 - based on the shadow of the Earth on the Moon
 - Calculated the circumference of the Earth using ratios of shadows in two places at the same time

Geocentric Model of Universe

- Heraclides (330 B.C.) develops model based on movement in sky, i.e. the moon passes in front of sun, etc.

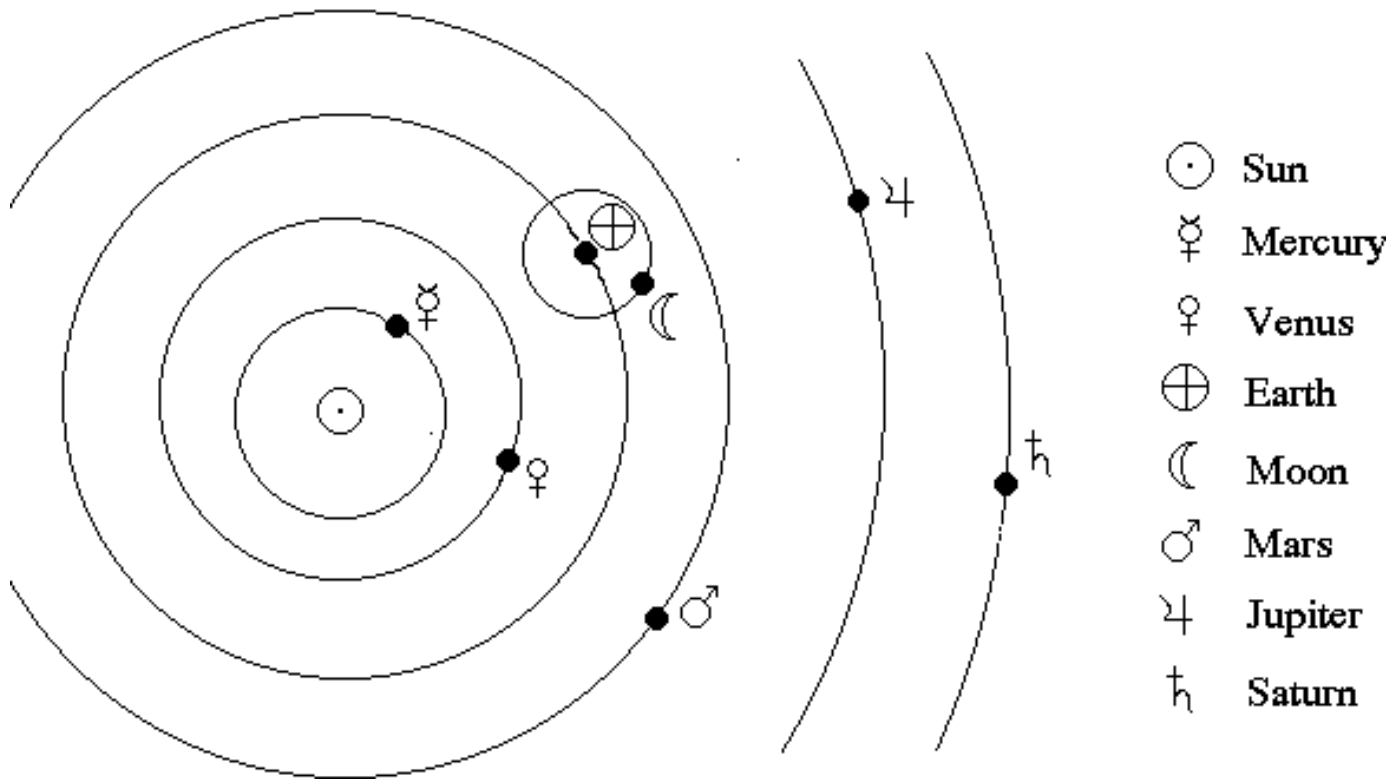
Geocentric Solar System Model



Heliocentric theory

- Aristarchus (230 B.C.) develops theory and considers the sun as “central fire”

Heliocentric Solar System Model

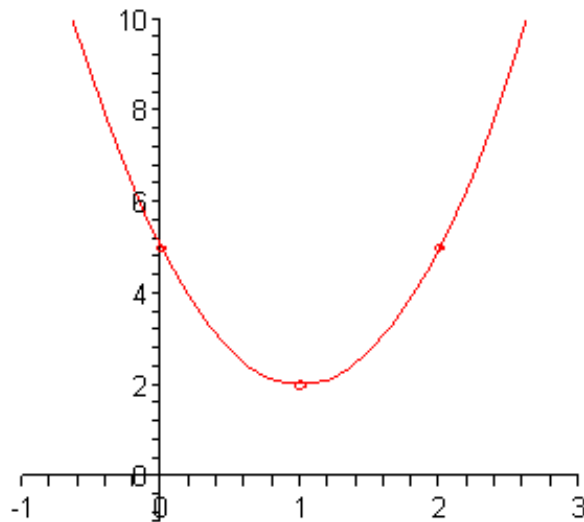


Heliocentric Theory rejected mainly for these reasons

- Earth is moving
 - If the earth is moving, why can't we feel it move through space?
- Earth is at the center
 - Fits with Aristotle and Plato's teachings
- Earth observers do not observe stellar parallax

Parallax - root

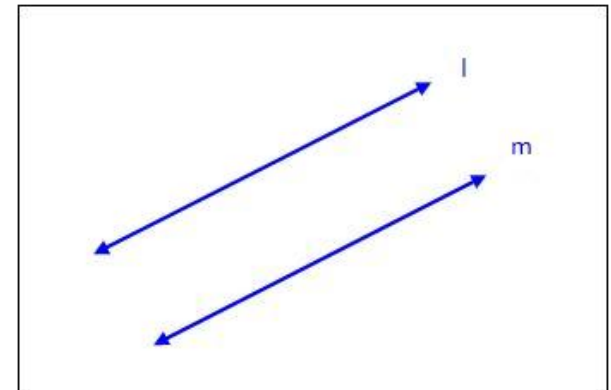
- Para – Greek root meaning
 - at or to one side of, beside, side by side
 - ex: parabola, paragraph, parallel



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Parallax before your very eyes!

- Close one eye
- Hold out your thumb and cover up one of the letters
- Without moving your thumb, open your eye and close the other

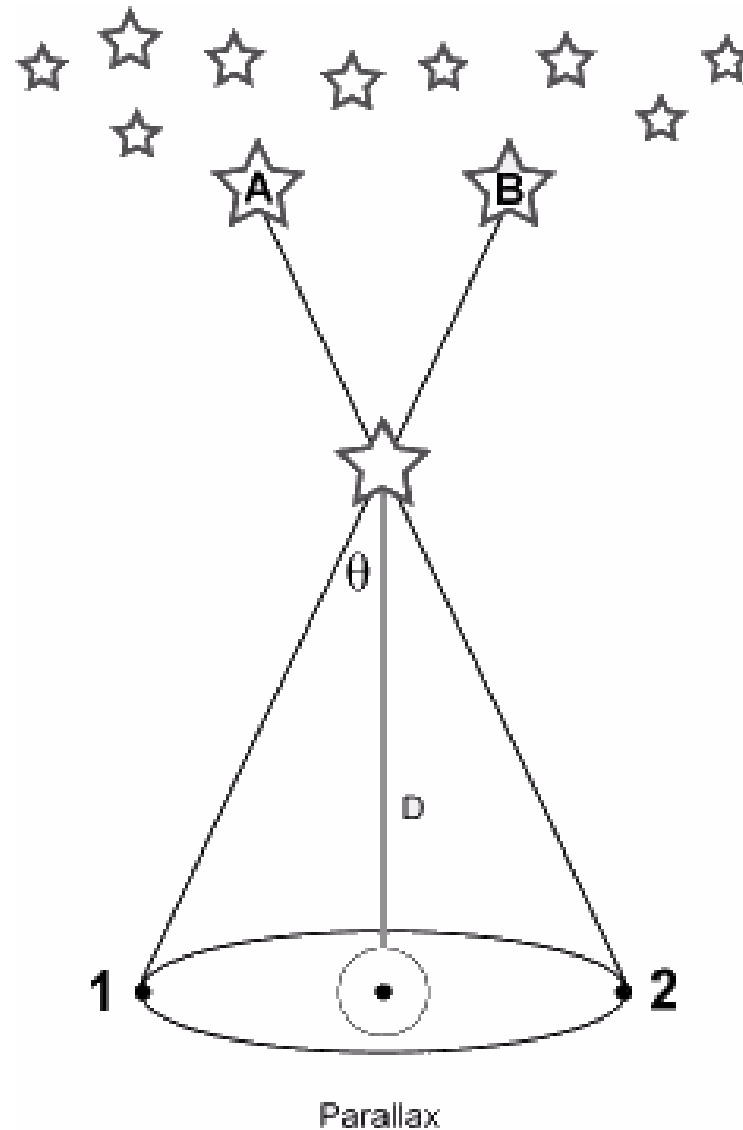
A

B

C

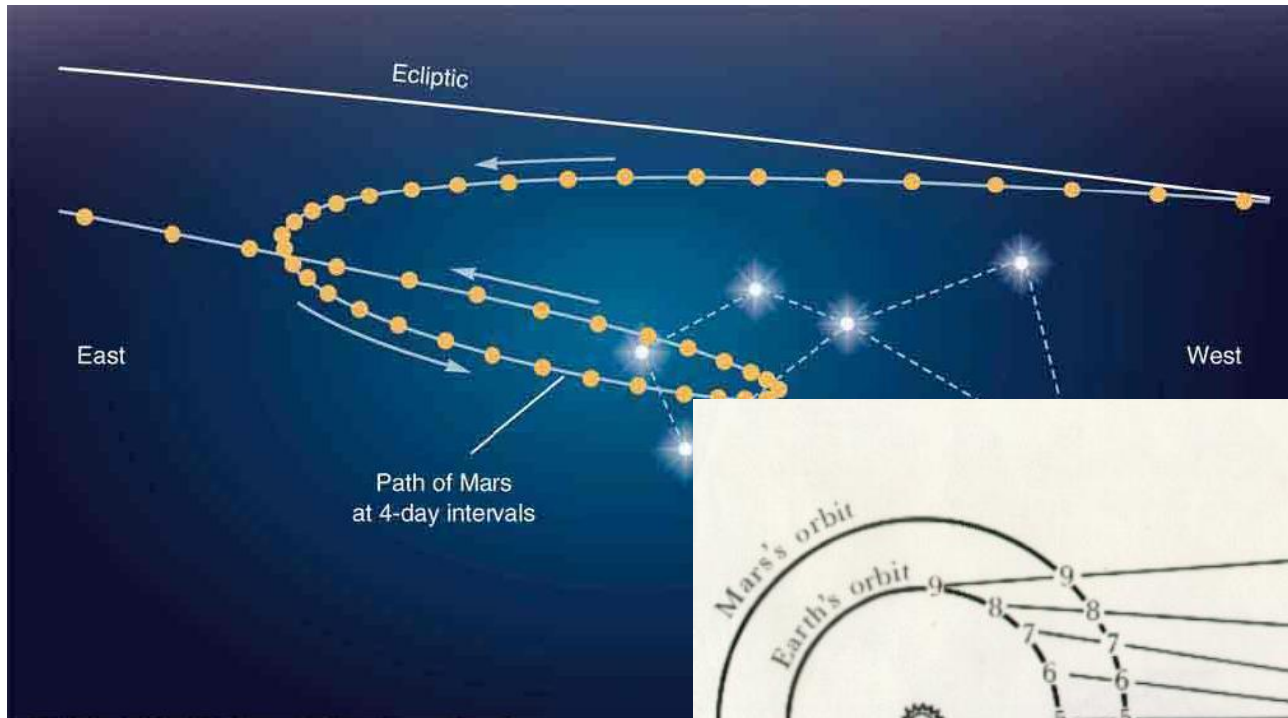
- Apparent shift in position from two lines of sight

Stellar parallax

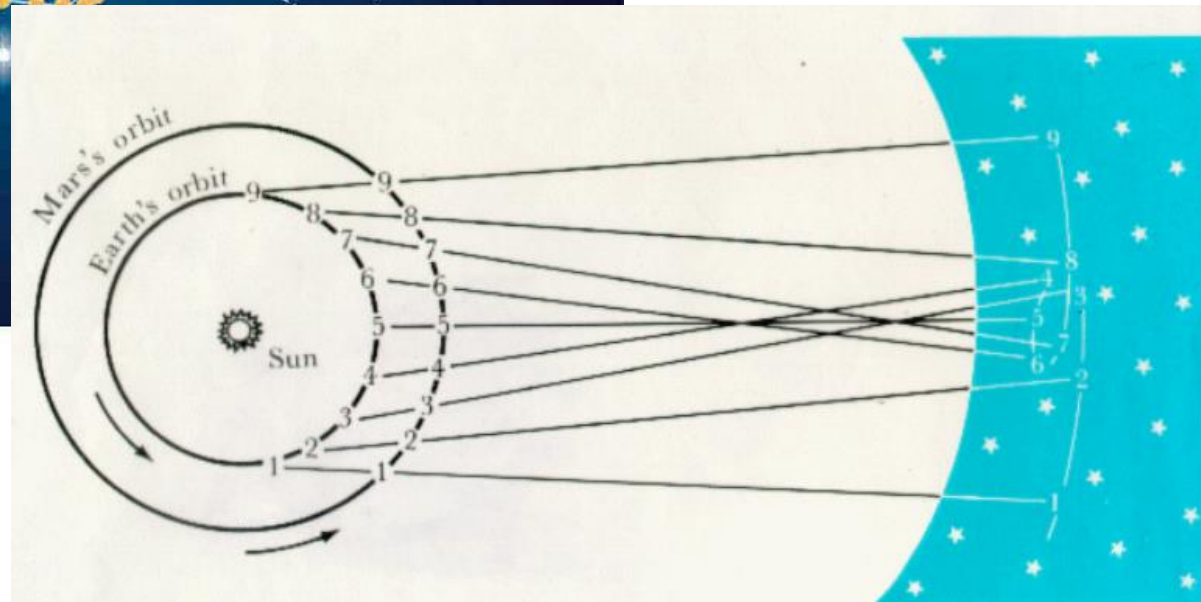


Geocentric Model flaws

- Retrograde motion of Mars unexplained

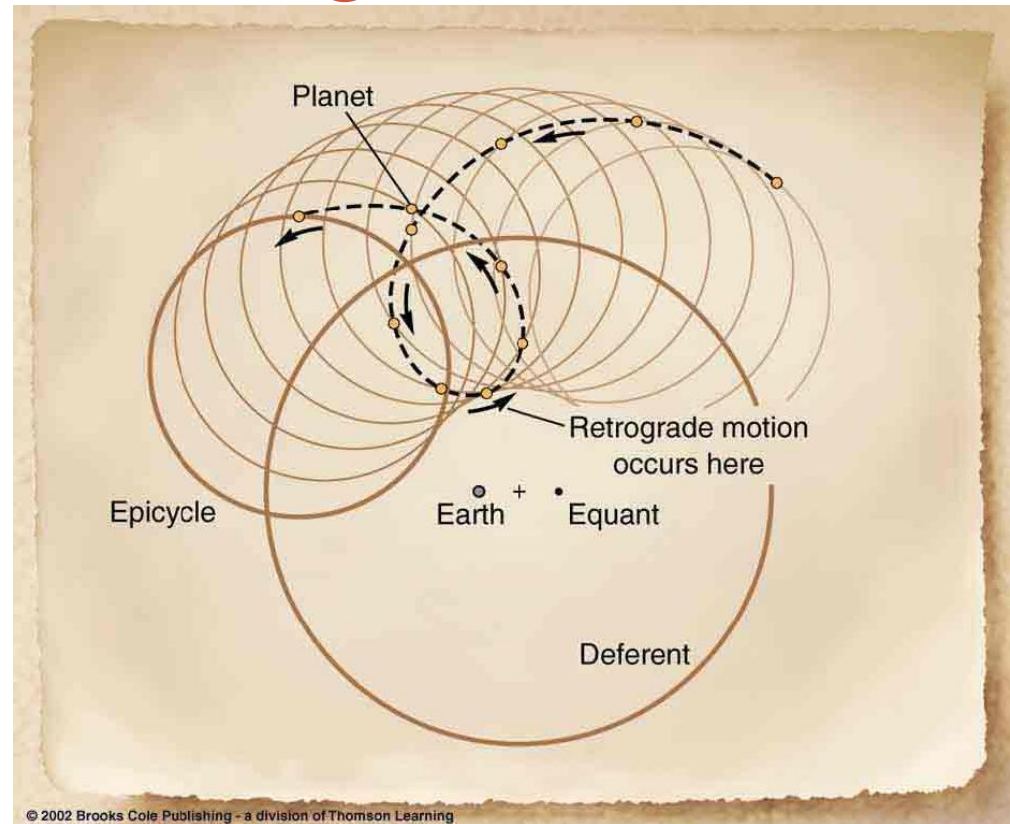


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Ptolemy's redesign

- Epicycles

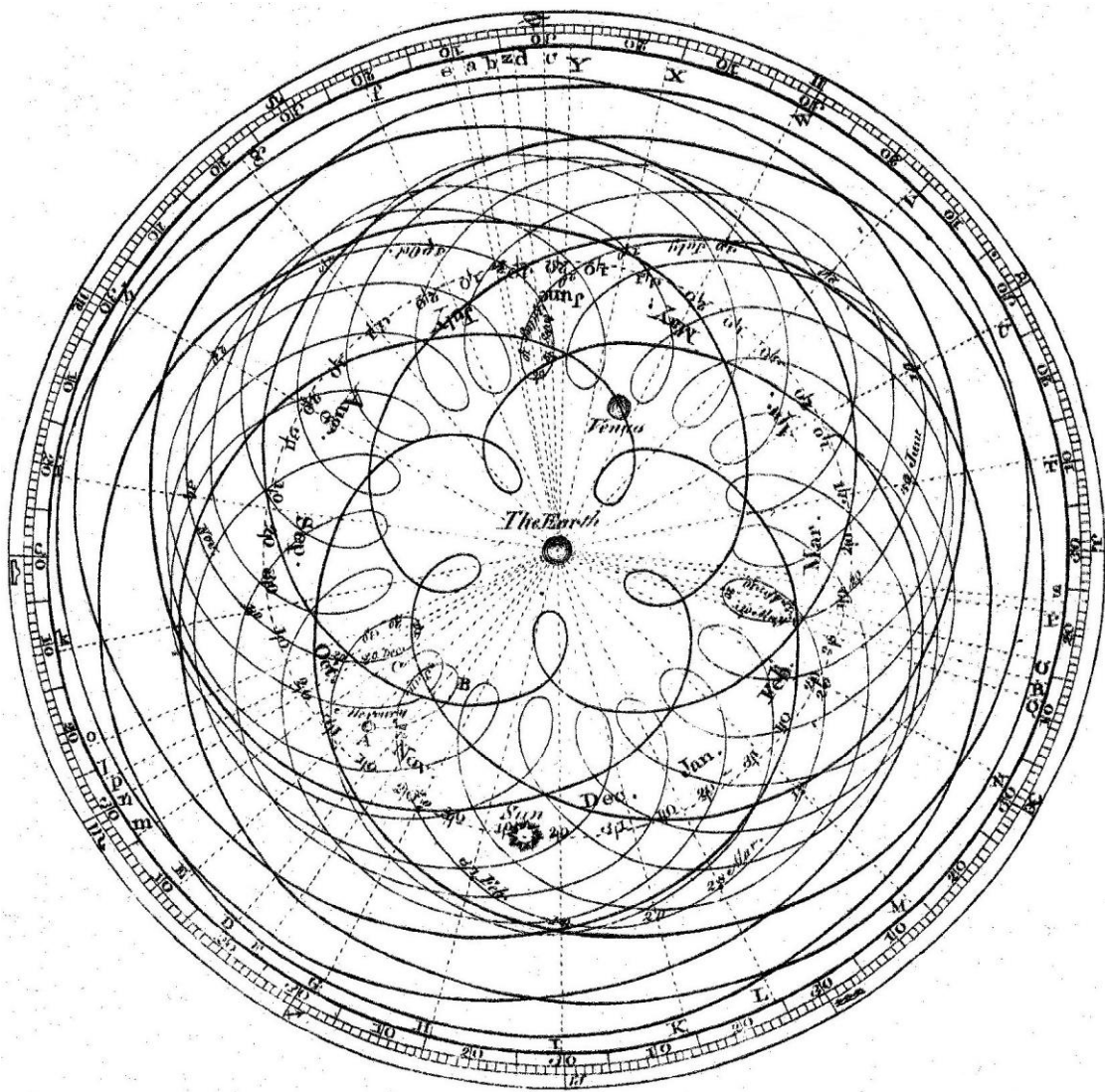


- Geocentric model remains unquestioned for ~1400 years!
- Good, but not good enough. Added many epicycles in attempt to improve accuracy

Copernicus (1473 – 1543)

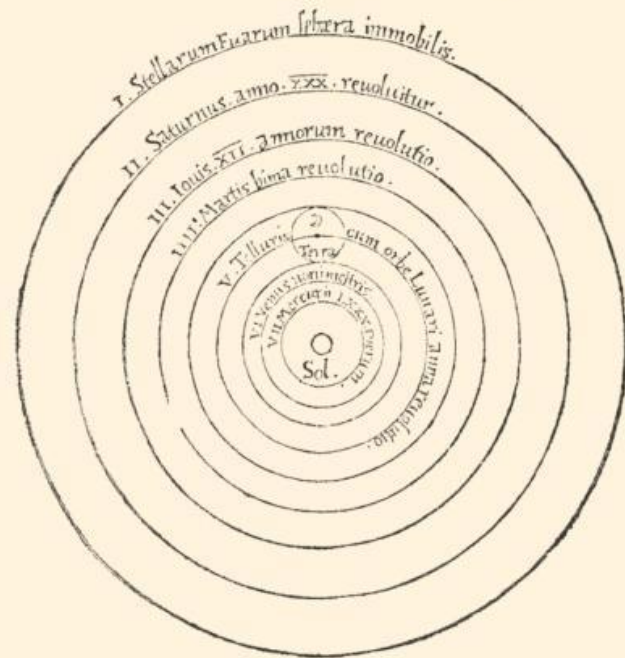
- Alexandria burns, Roman culture collapses, Dark Ages
- Renaissance welcomes new ideas
- Copernicus challenges the Church
 - suggests heliocentric model is more elegant and easily explains retrograde motion





NICOLAI COPERNICI

net, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quanto loco Venus nono mense reducitur. Sextum denique locum Mercurius tenet, octuaginta dierum spacio circū currens. In medio uero omnium relidet Sol. Quis enim hos



pulcherrimo templo lampadem hanc in alio uel meliori loco poneret, quam unde totum simul possit illuminare: Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegistus uisibilem Deum, Sophoclis Electra intuentē omnia. Ita profecto tanquam in folio regali Sol residens circum agentem gubernat Atirorum familiam. Tellus quoque minime fraudatur lunari ministerio sed ut Aristoteles de animalibus ait, maximam Luna cum terra cognationē habet. Cōspicit interea à Sole terra, & impregnatur anno partu. Inuenimus igitur sub

Galileo (1594 – 1642)

- Was able to make clear observations about the night sky using simple telescope
- Big discoveries
 - Moons of Jupiter



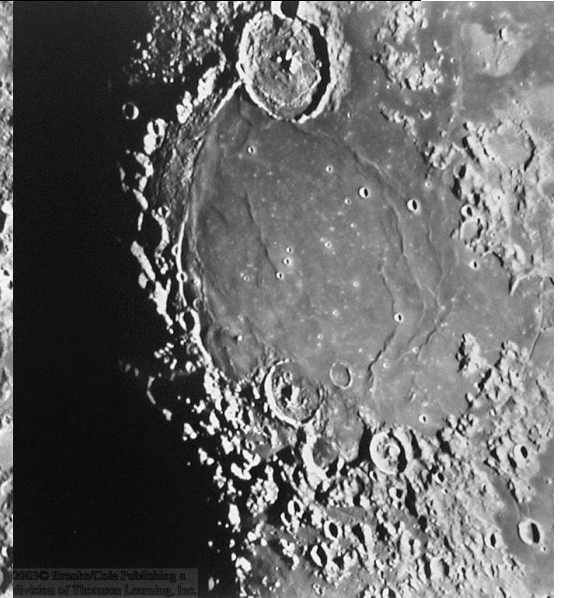
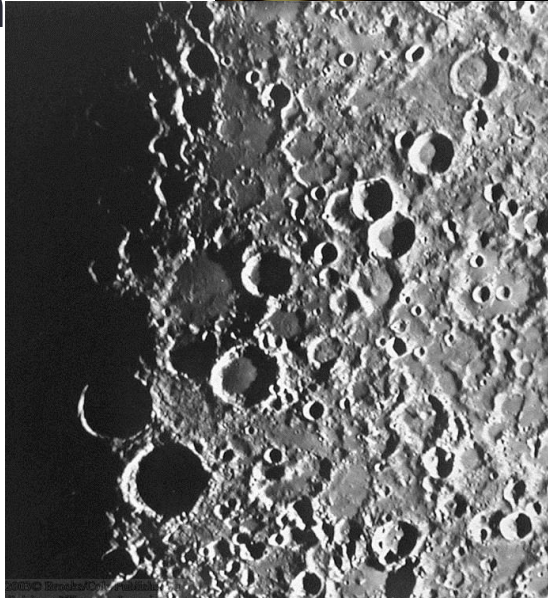
- Suggested analogous structure of solar system
 - Smaller bodies orbiting a large body
- We currently know of 63 moons orbiting Jupiter
 - 4 Galilean moons are the largest (Io, Europa, Ganymede, Callisto)

Galileo (2)

- Rings of Saturn

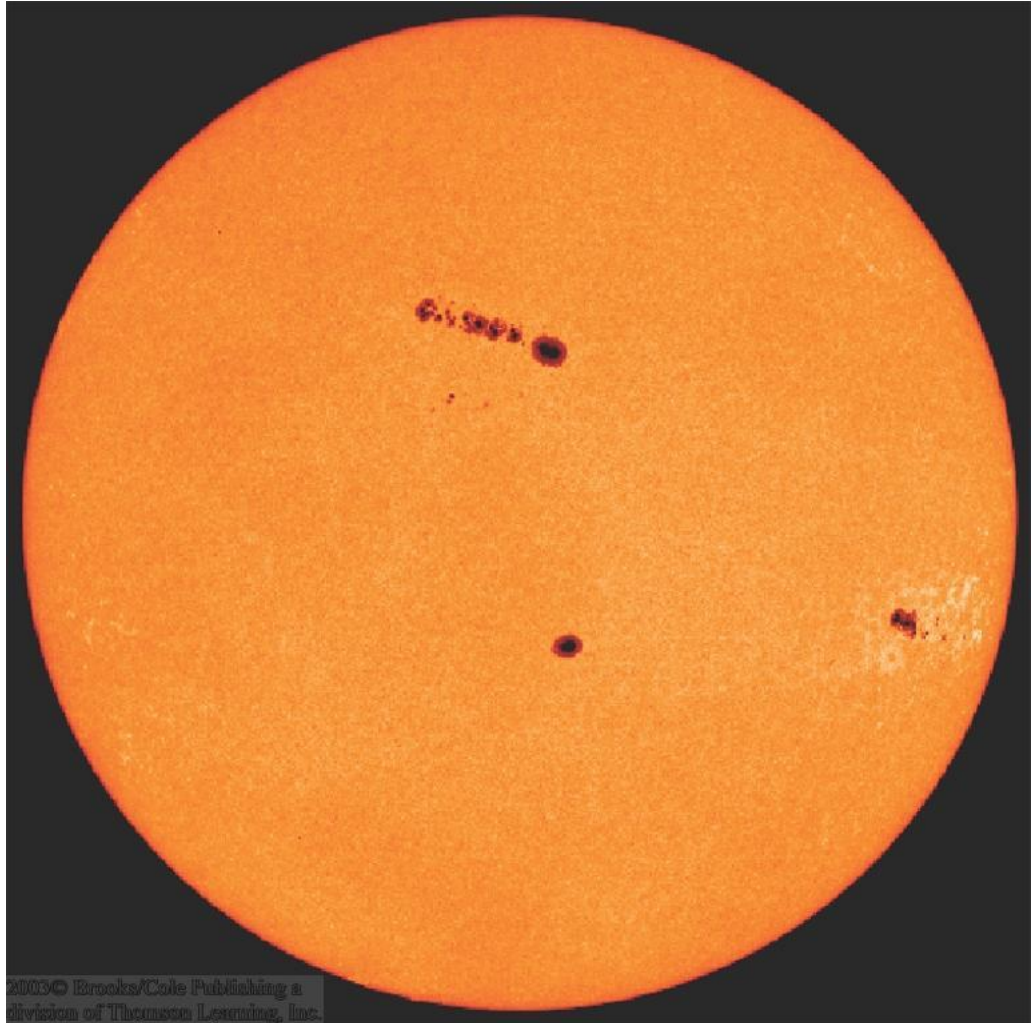


- Surface of the moon
 - Cratered, not smooth
 - “heavenly” body?



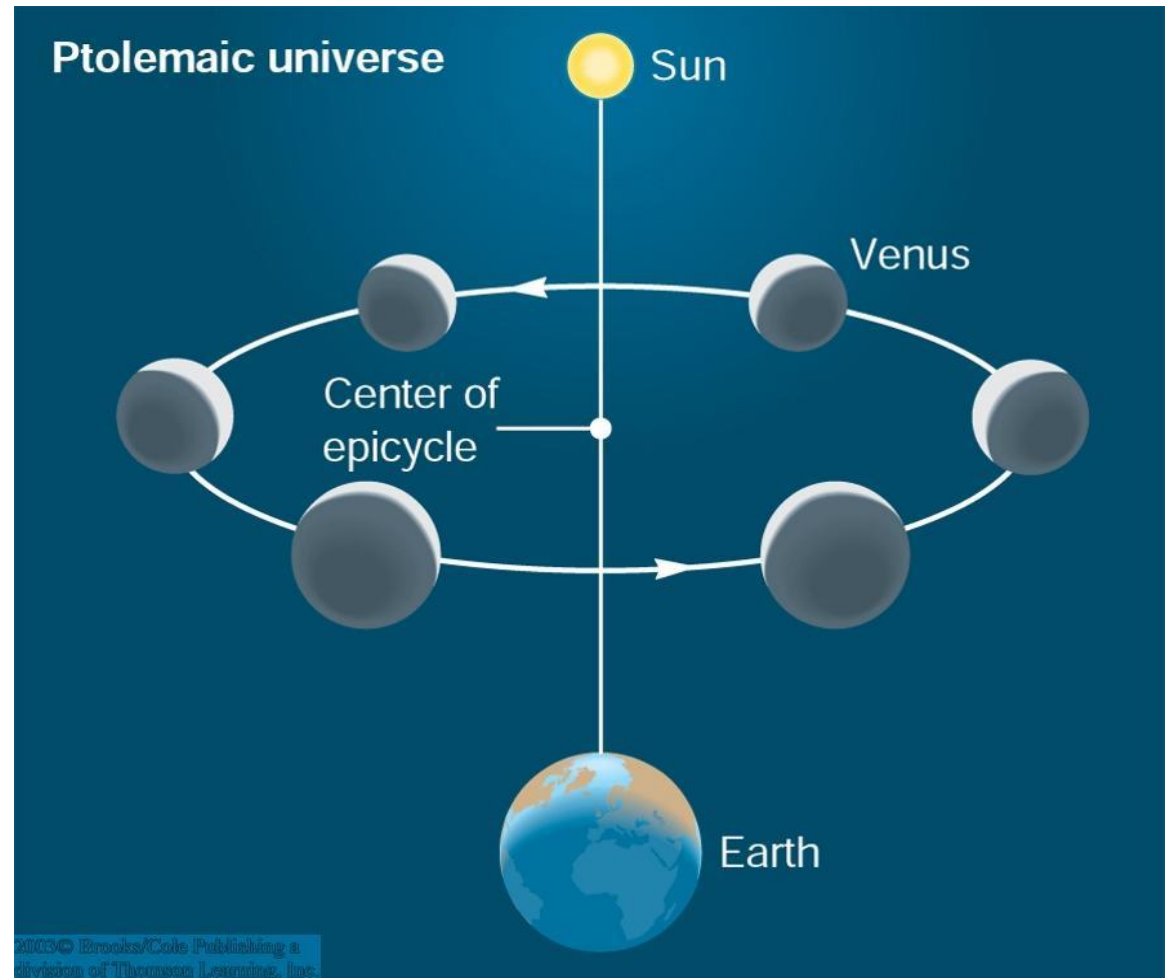
Galileo (3)

- Spots on the surface of the sun
 - Sun also not perfect
- Prolonged study of the sun contributes to his eventual blindness



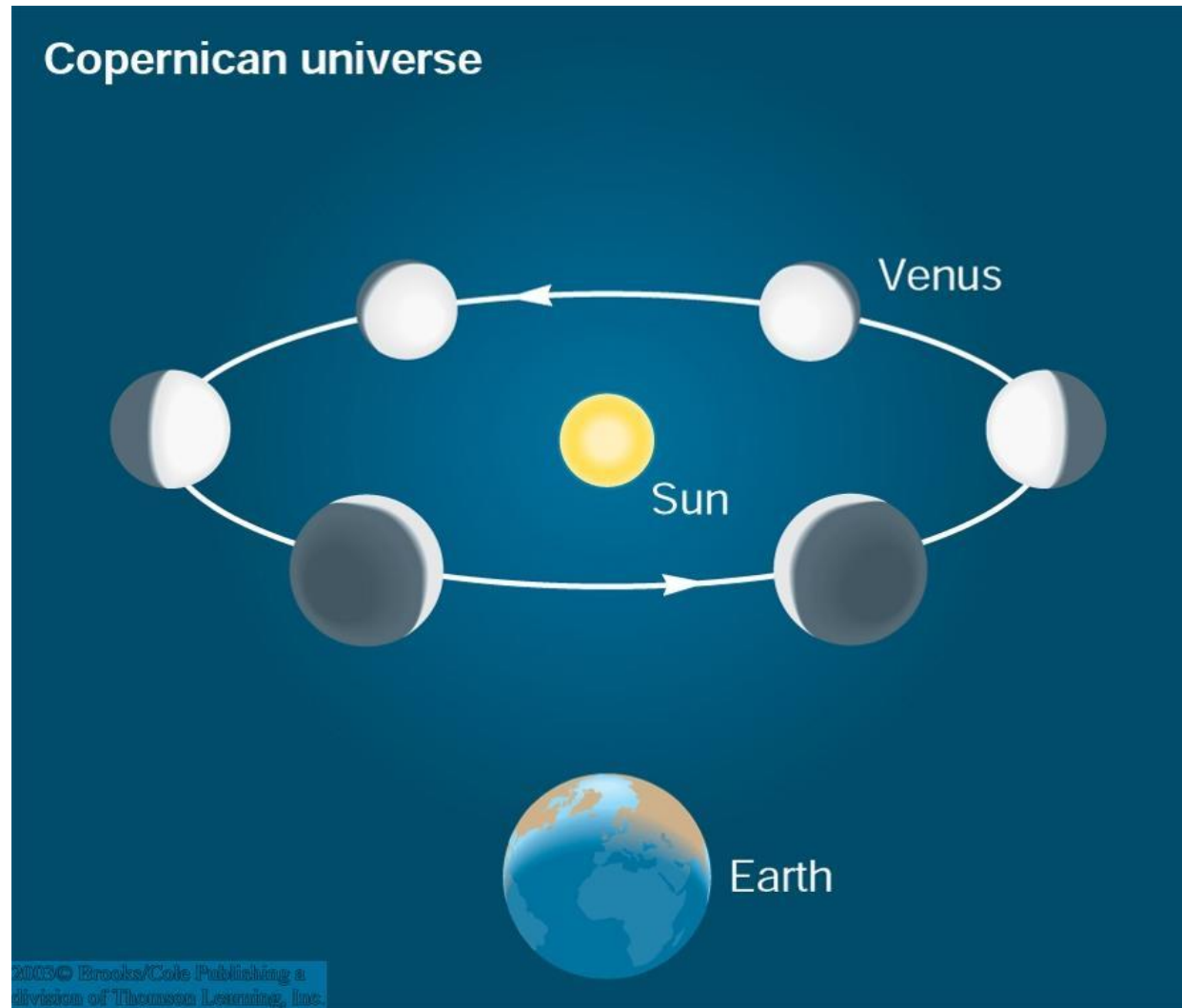
Galileo (4)

- Geocentric model predicts Venus exhibiting partial phases



Galileo (5)

- Heliocentric model predicts Venus exhibiting Full phases
- When Galileo points the telescope at Venus and sees a full Venus, he immediately understands the implications of the discovery
- Heliocentric model becomes irrevocably true as backed up by evidence



Tycho Brahe and Johannes Kepler

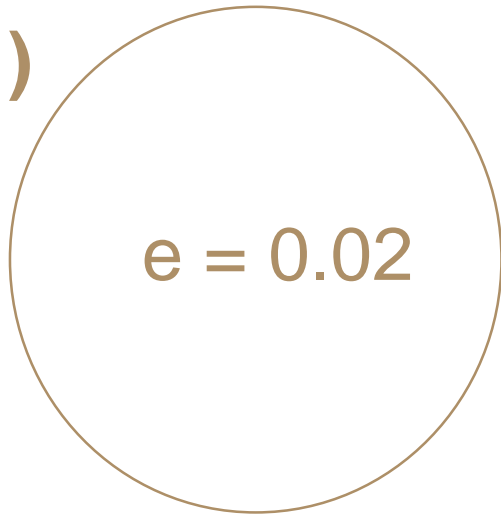
- Tycho Brahe (1546 – 1601)
 - Meticulous observer
 - 20+ years of notes on positions of planets
- Johannes Kepler
 - Student of Brahe
 - used the tables to study mathematically
- Abandoned the previous principles
 - Planets do not move in circular orbits
 - Planets do not move at a uniform speed

Elliptical orbits

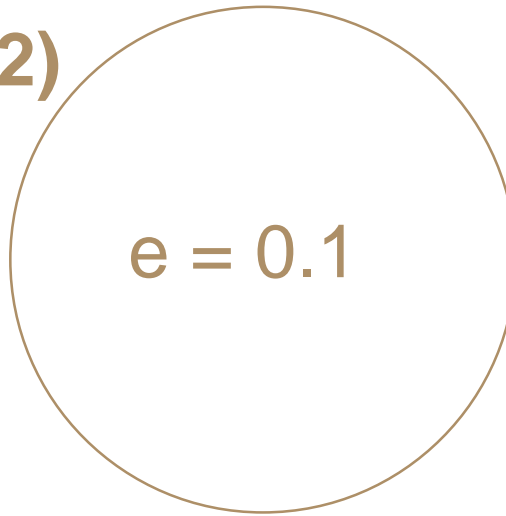
- Carefully aggregates all data points and attempts to find a pattern
- How oblong (warped, uneven, flattened) an ellipse looks is based on its eccentricity
 - Circles have eccentricity of 0 (no flatness)

Elliptical orbits (2)

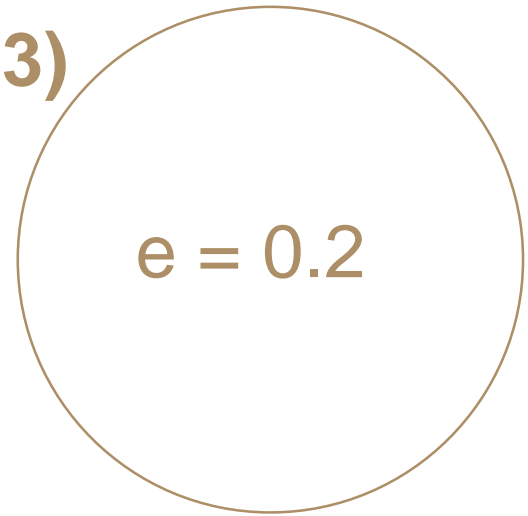
1)



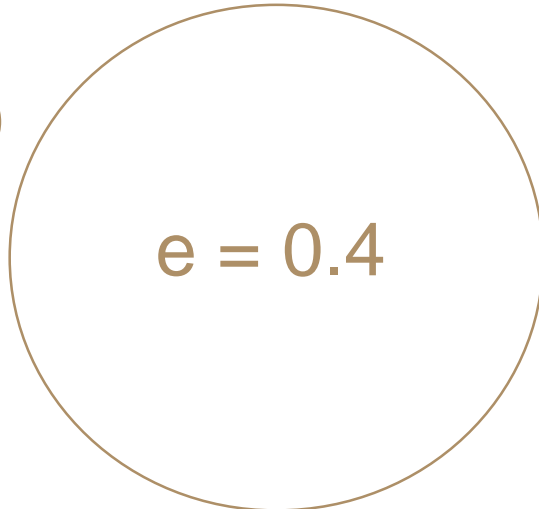
2)



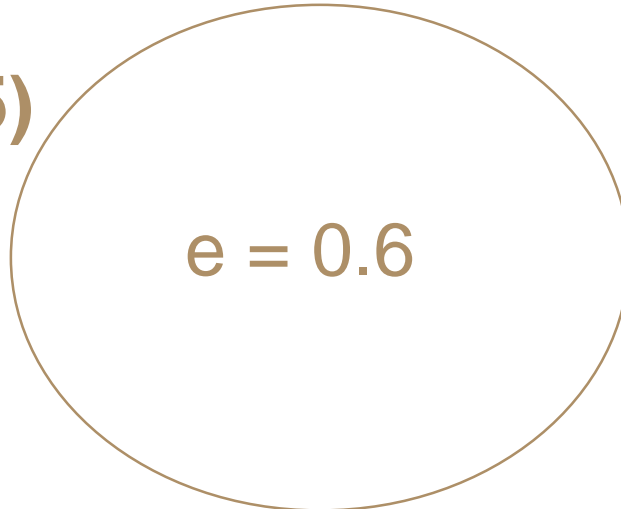
3)



4)



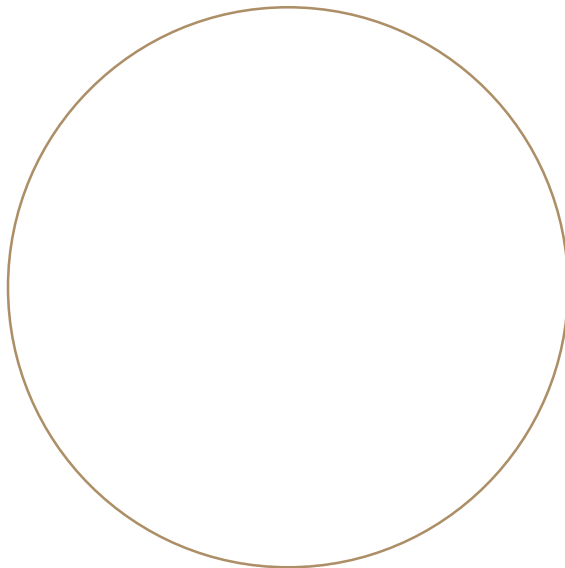
5)



Elliptical orbits (3)

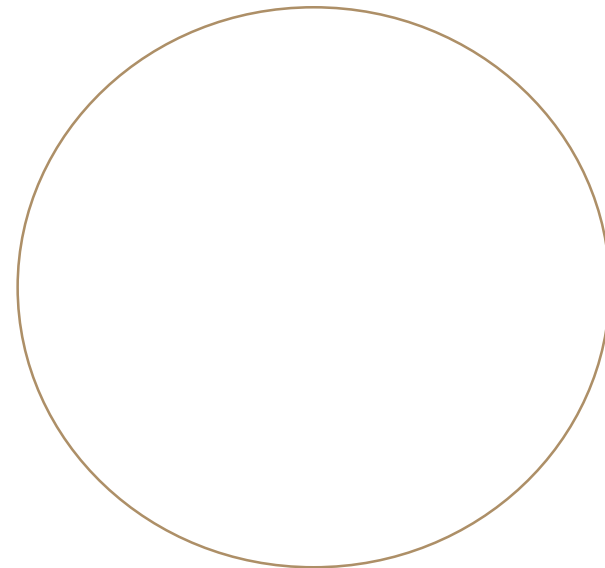
Orbits of planets are virtually indistinguishable from circles:

Earth: $e = 0.0167$



Most extreme example:

Pluto: $e = 0.248$

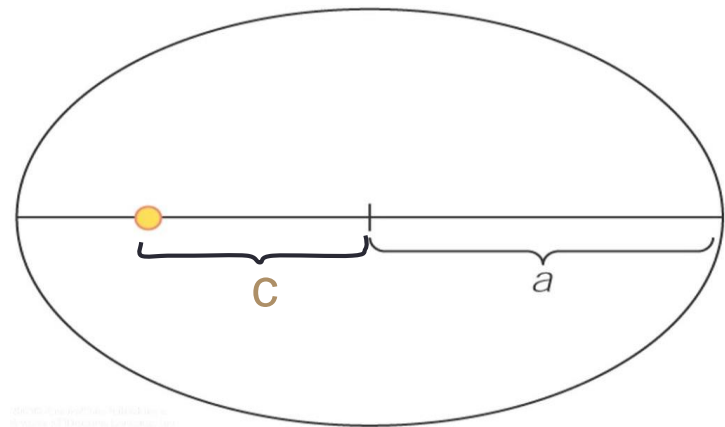
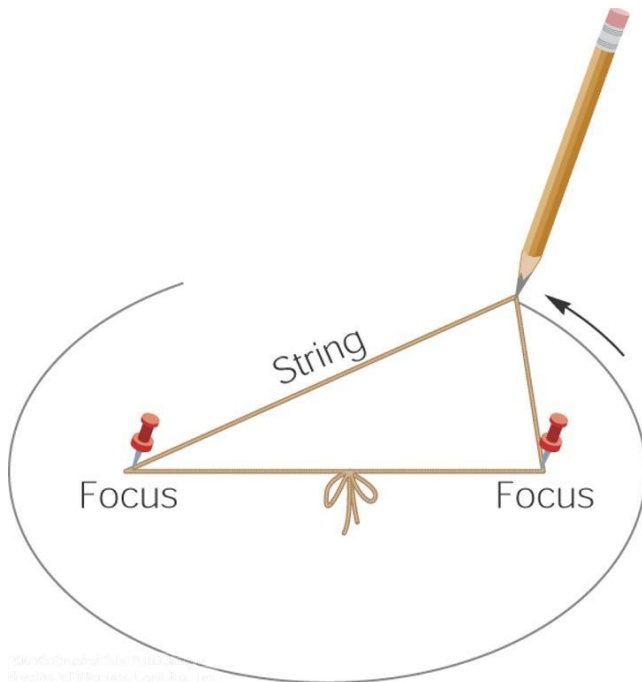


Elliptical orbits (4)

- Were early astronomers wrong?
- Orbits look circular to naked eye
 - Very little eccentricity
- More precision due to improvements in tools changed their perception of orbits

Kepler's 1st Law of Planetary Motion

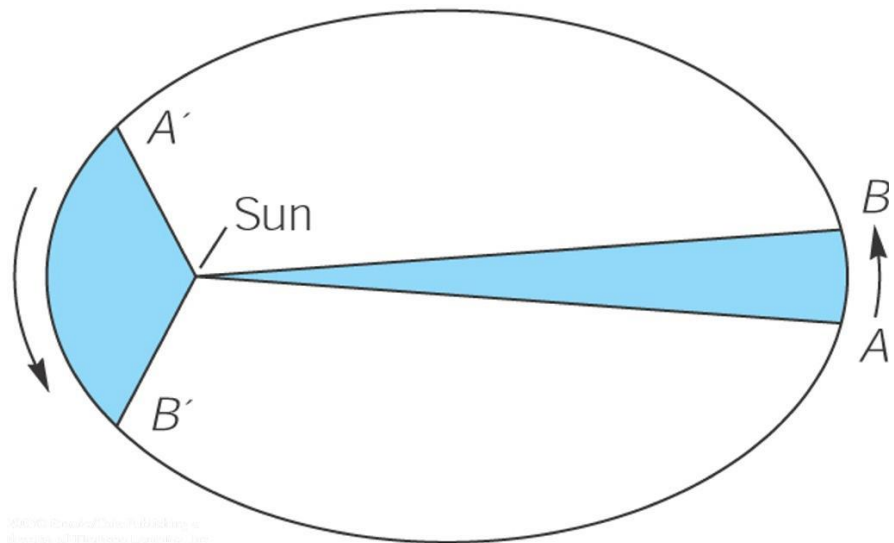
- The orbits of the planets are ellipses with the sun at one focus.



$$\text{Eccentricity } e = \frac{c}{a}$$

Kepler's 2nd Law of Planetary Motion

- A line from a planet to the sun sweeps over equal areas in equal intervals of time.
- i.e. planets travel fastest when they are close to the Sun and slower when they are farthest away from the Sun.



Kepler's 3rd Law of Planetary Motion

- Time to travel around the solar system follows this peculiar pattern:
- A planet's orbital period (P) squared is proportional to its average distance from the sun (a) cubed:

$$P_y^2 = a_{AU}^3$$

(P_y = period in years;
 a_{AU} = distance in AU)

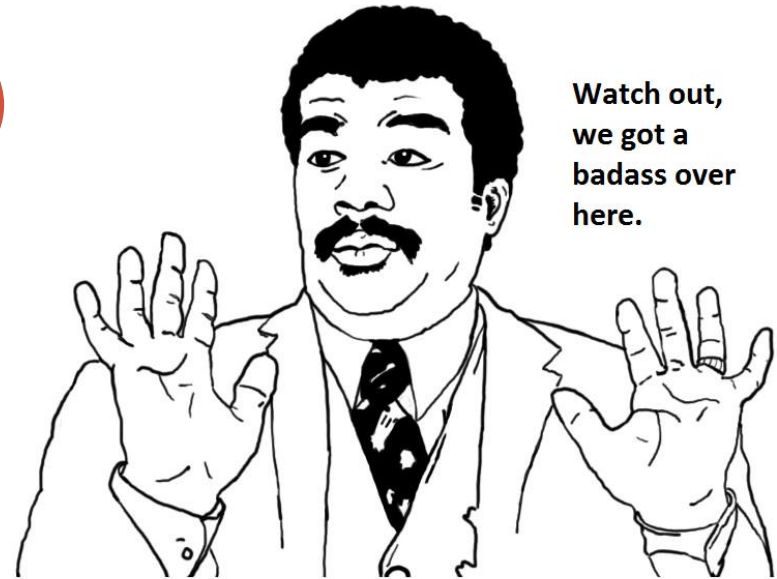
- Conclusion: Planets move in elliptical orbits at a non-uniform speed
- Still puzzling: What keeps planets revolving around the Sun?

Newton (1643 – 1727)

<http://bigthink.com/videos/my-man-sir-isaac-newton>

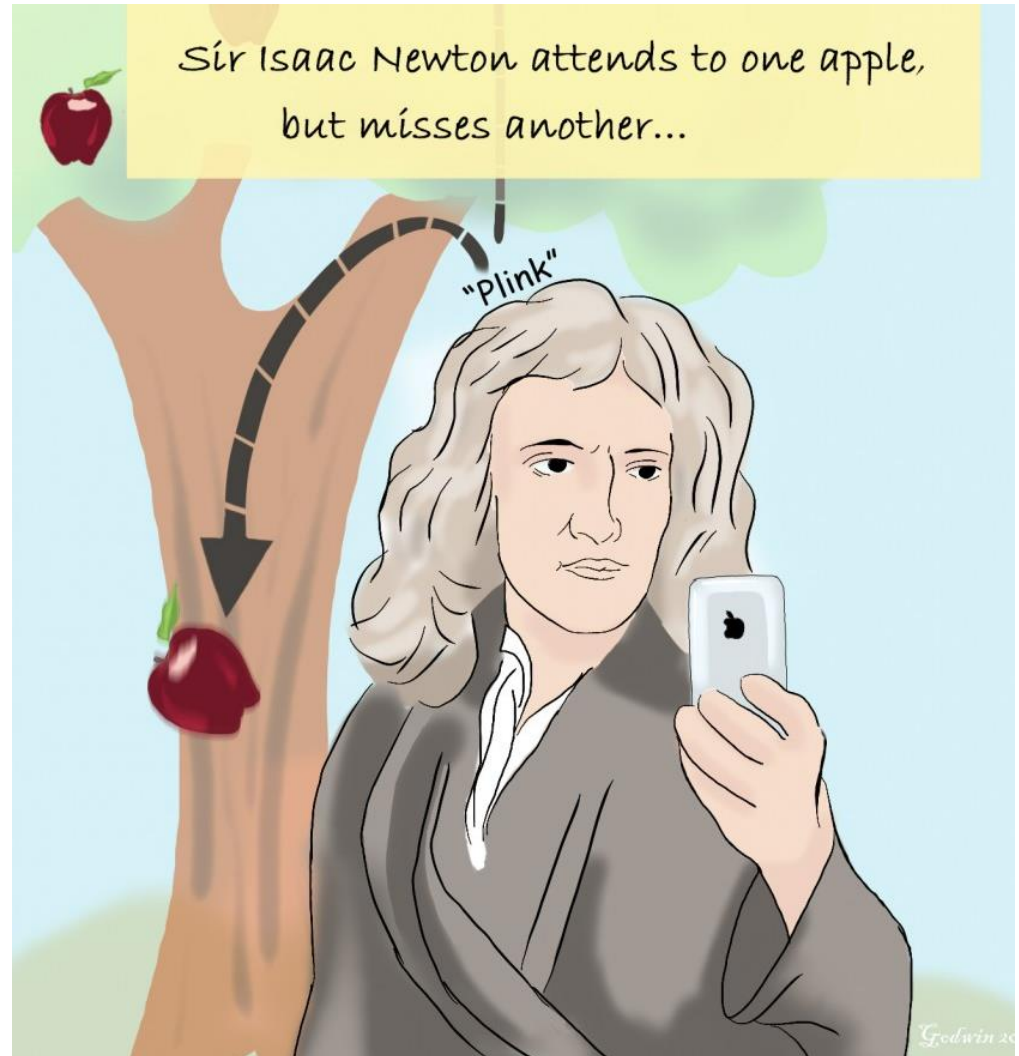
Newton (1643 – 1727)

- Discovered Three Laws of Motion
 - Inertia
 - $F_{\text{net}} = ma$
 - Cannot touch without being touched!
- Invented calculus as a necessary tool to solve mathematical problems related to motion
 - On a dare!
- Discovers laws of optics



Newton (2)

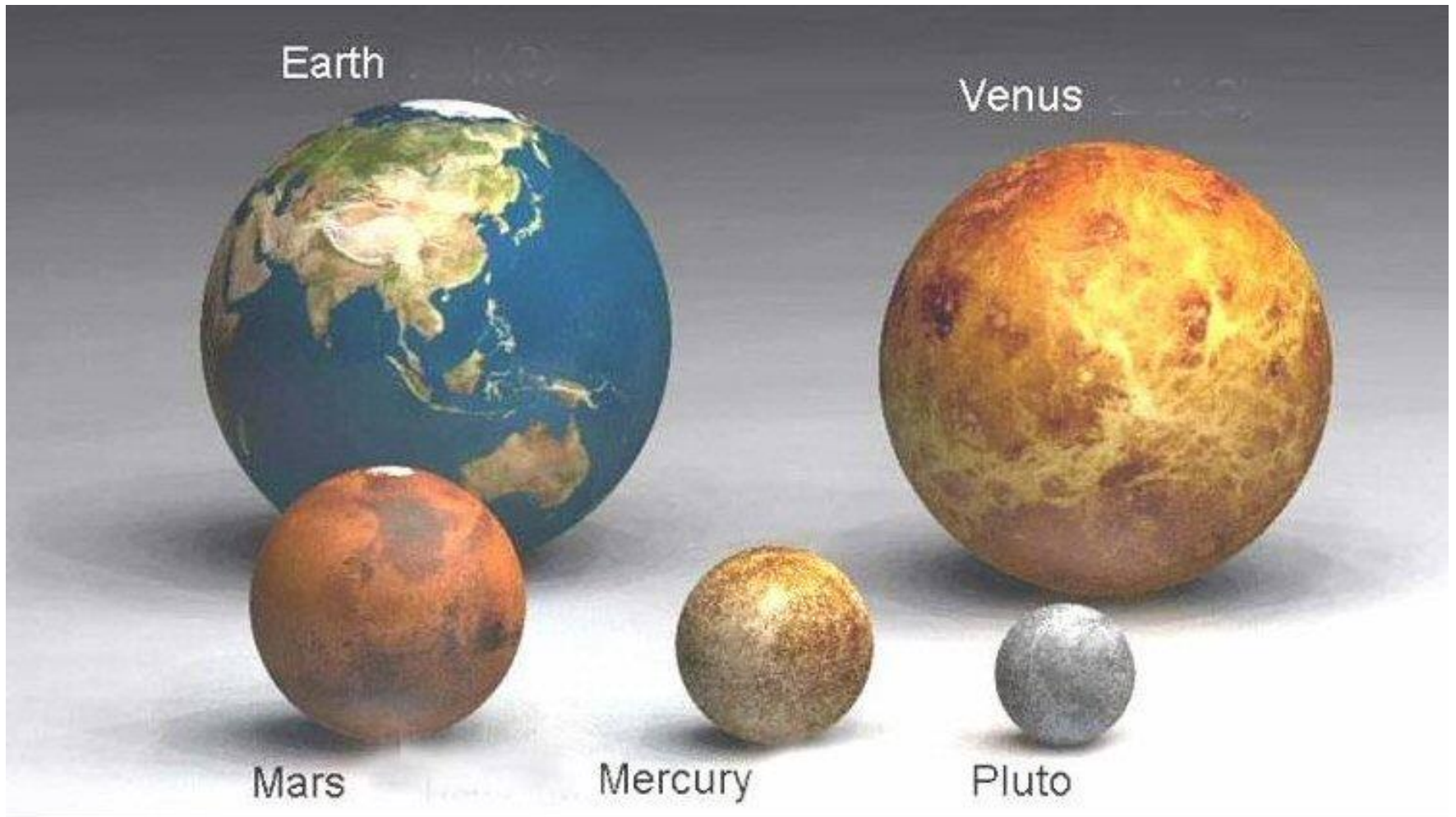
- Attributed with “discovering” gravity
 - FALSE! Newton’s actual discovery is far grander
- Newton witnessed an object (possibly an apple) fall across his field of vision at the same time he was pondering the motion of the planets
- His EUREKA moment was combining the fact that the **SAME** force that acts on the apple **ALSO** acts on the planets!
 - What pulls the apple “down” also pulls the planets around the Sun.



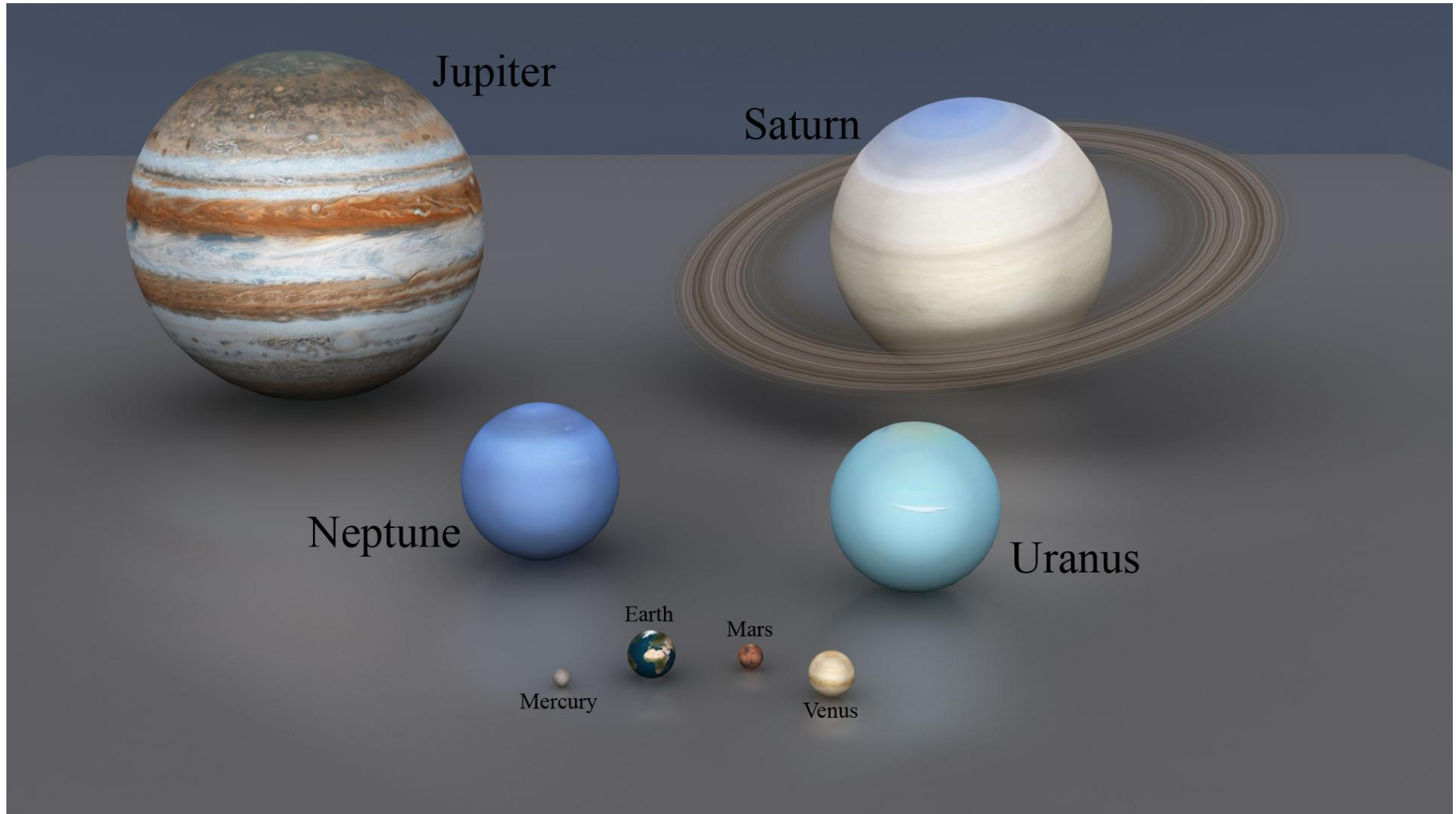
Einstein, Hawking and Beyond

- Space-Time duality
- Special Relativity
- $E = mc^2$
- Black hole radiation
- Expansion of the universe

Where am I?



Where am I?



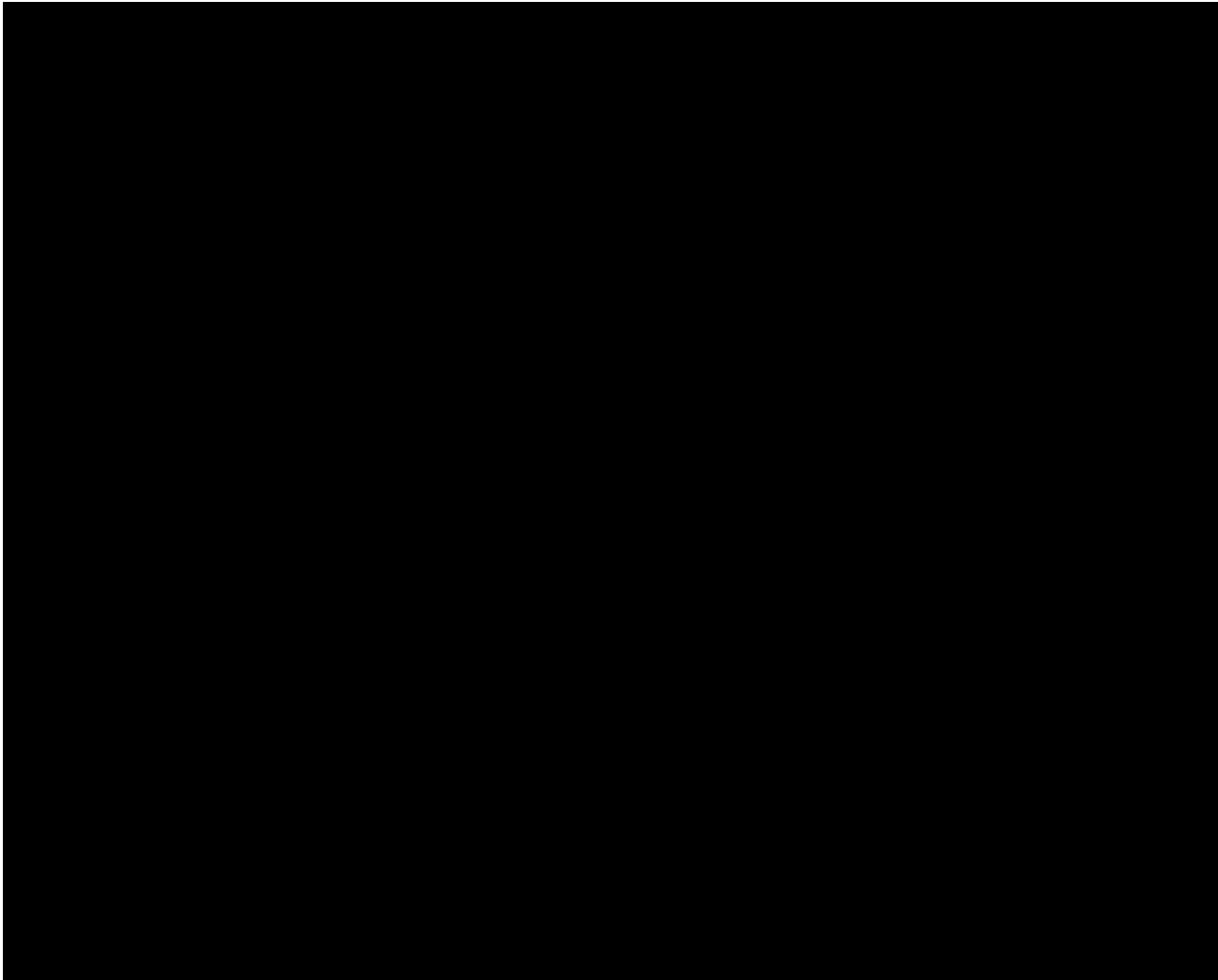
Where am I?

Sun



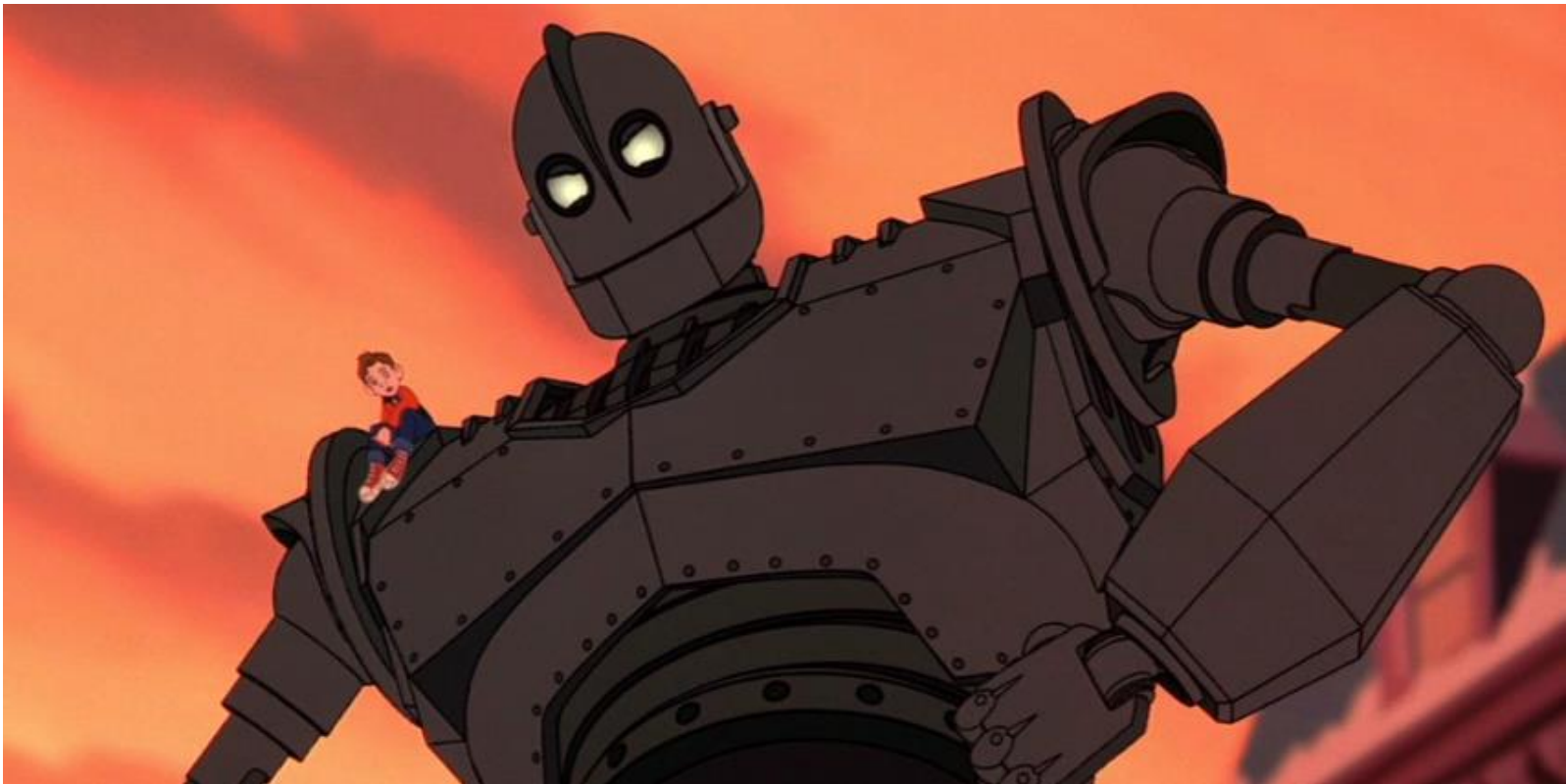
Where am I?

<https://vimeo.com/19568852>



Where am I? What time is it?

- “If I have seen further, it is by standing on the shoulders of giants” – Newton



Where am I? What time is it?

- “If I have seen further, it is by standing on the shoulders of giants” – Newton
- By the sheer act of existing on this small, blue orb rotating, revolving around a medium-sized, middle-aged star, YOU are a part of a great and tremendous history.
- You are standing on the shoulders of a giant that is bigger than all of the great physicist’s giant.
- What do you see?