



# **Chapter 4**

## **The Origin of Modern Astronomy**

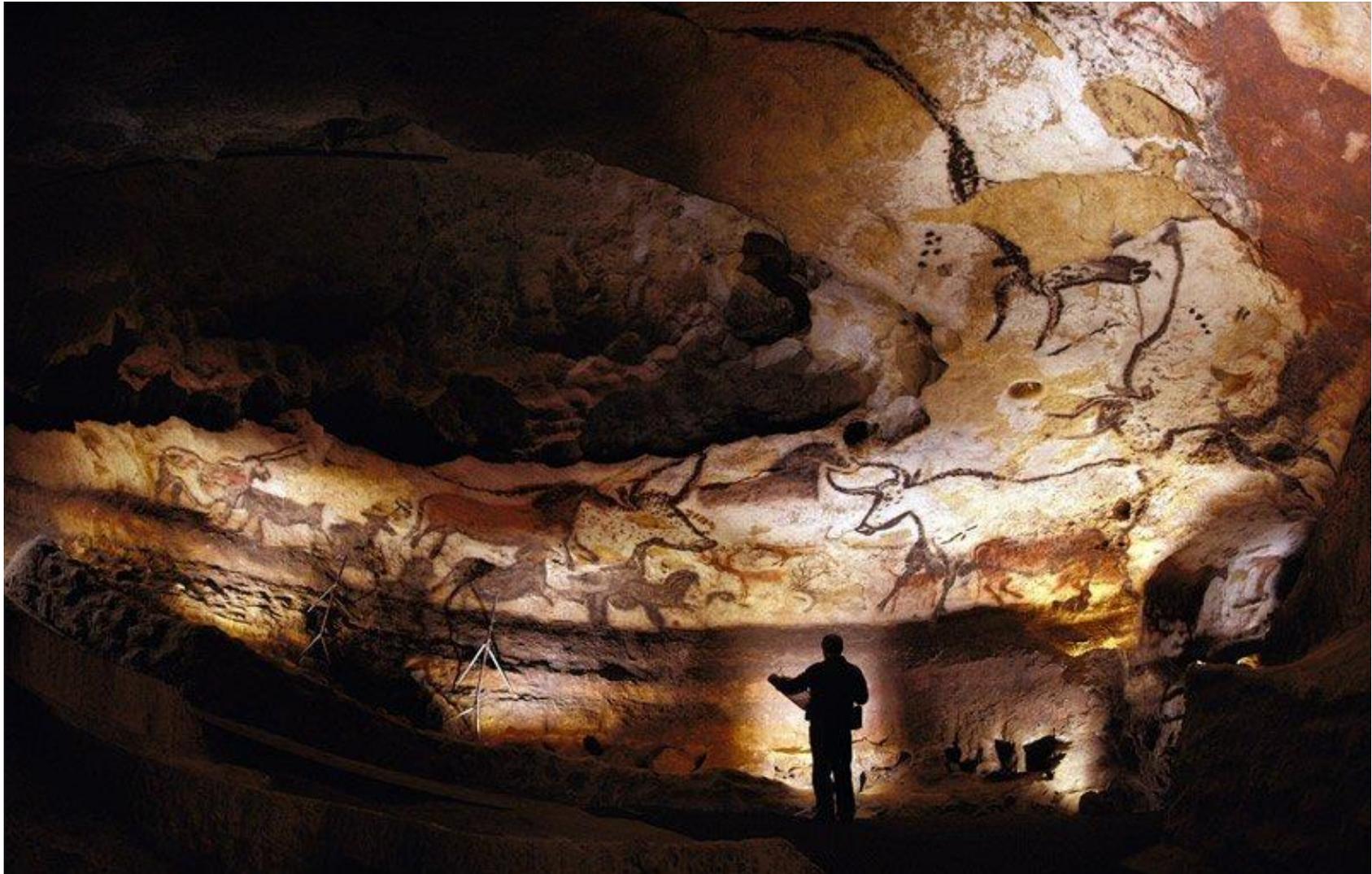
# Earliest Evidence

- 15,000 Year old  
Lunar Calendar



Displays Moon Going  
Through various phases.

Location: Lascaux in France



# The Biggest Mystery

- Human civilization hasn't yet changed for tens of thousands of years, then suddenly



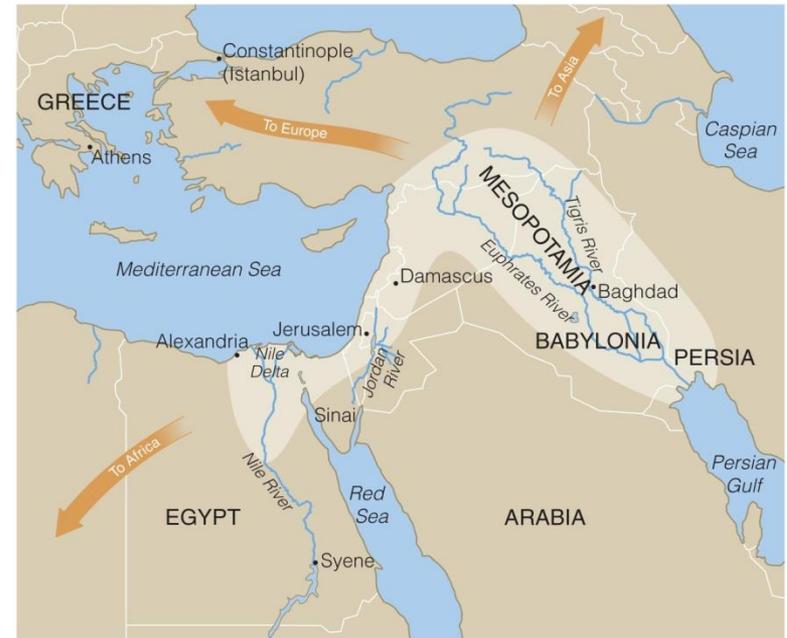
# Sumerians



# Mesopotamian Astronomy

- MESOPOTAMIANS built observatories starting ~10000 years ago:
- the *ziggurat* had seven levels, one for each wandering object in the sky:
- Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn
- Thus 7 days to the week
- They tracked stars --- groups rising before sun at different times of year implied seasonal beginnings for *harvesting* and *planting* (zodiac).
- Divided circles in 360 degrees, each degree into 60 minutes and each minute into 60 seconds -- we still use!
- Left written records in cuniefom so we understand them better

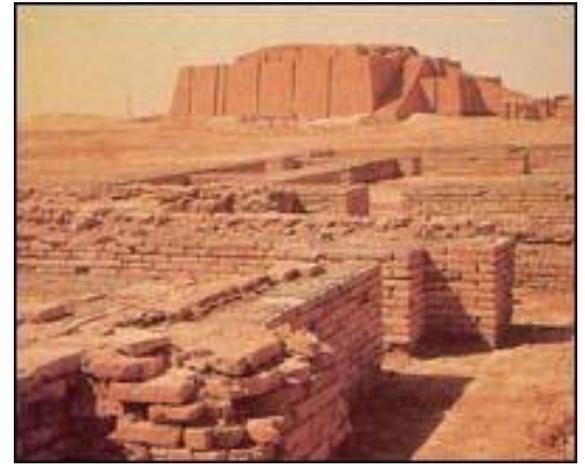
# Mesopotamian Astronomy and Influence



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- By 2000 BC Ur and other Sumerian and Babylonia cities had large temples, or ziggurats, usually aligned N-S, like most Egyptian pyramids
- Egyptian and Mesopotamian knowledge *passed* to Europe, Asia and Africa

# Sumerians (10,000 B.C.)



## Babylonians (3000 BC)

- Mathematical theory rather than just observations
- Motions of the sun and moon
- Provided the first evidence that the earth is round
- Developed basic constellations and astrology
- Introduced the 24 hour day
- Developed a lunar calendar



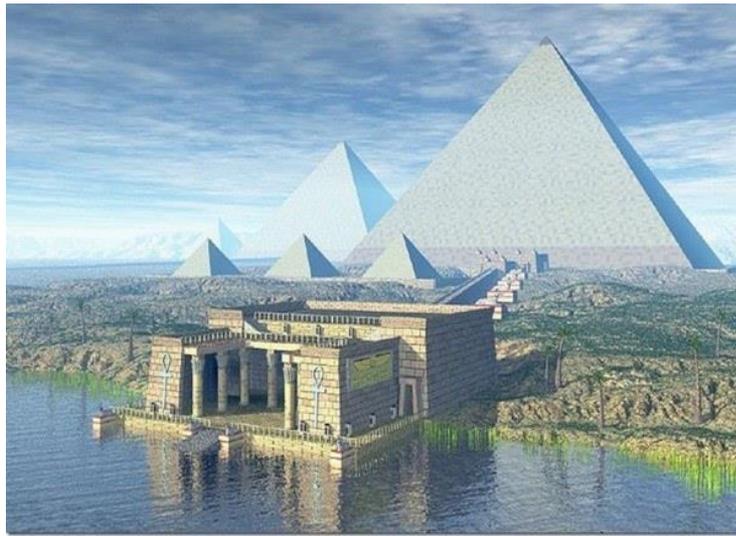
# Temple of Baal



# Ancient Egyptians

Structures aligned to solstices, Orion constellation special significance for God Osiris.

Religion Permeated and Directed their society, and their gods were in the heavens





# Great Pyramids



# Passage of astronomical knowledge



Ancient Babylon

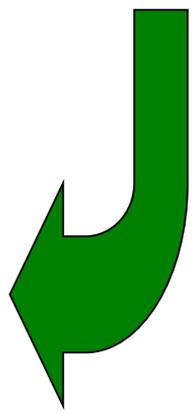
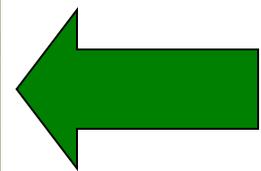


Ancient Egypt

Ancient Roman Empire



Ancient Greece

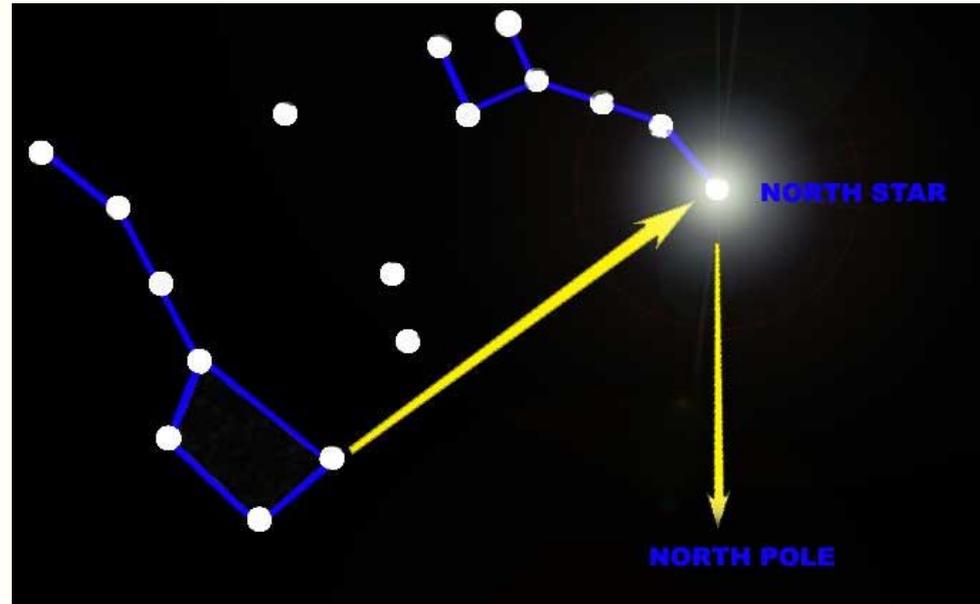


# Astronomy impacted ancient civilizations

The major driving force in ancient astronomy studies was *Survival*.

Rainy/Dry Season

Navigation



# Astronomy impacted ancient civilizations

## Europeans

*Stonehenge* is perhaps one of the best known sites of ancient astronomical pursuits.

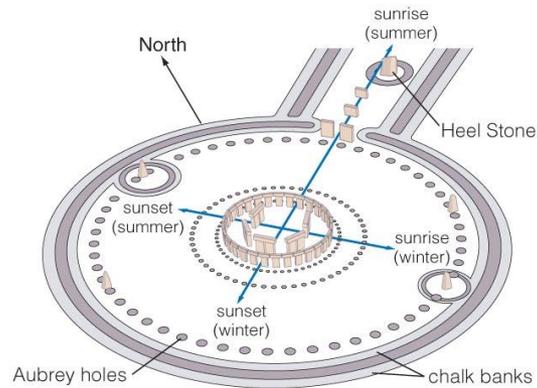


# Special Seasonal Alignments

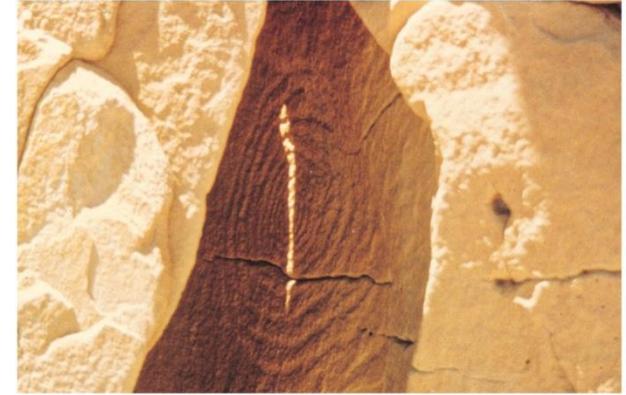


**a** The remains of Stonehenge today.

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**b** This sketch shows how archaeologists believe Stonehenge looked upon its completion in about 1550 B.C. Several astronomical alignments are shown as they appear from the center: For example, the Sun rises directly over the Heel Stone on the summer solstice.



**a** A single dagger of sunlight pierces the center of the carved spiral only at noon on the summer solstice.

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- Stonehenge (England -- and others) had many alignments for *predicting*, equinoxes and bright stars
- Sun Dagger (New Mexico) shows noon on summer solstice; other effects in winter & equinoxes

# Astronomy impacted ancient civilizations

## Native Americans:



The Big Horn Medicine Wheel in Wyoming is similar to Stonehenge in design

It was built by the *Plains* Indians

Its spokes align roughly with solstices and equinoxes

# Astronomy impacted ancient civilizations

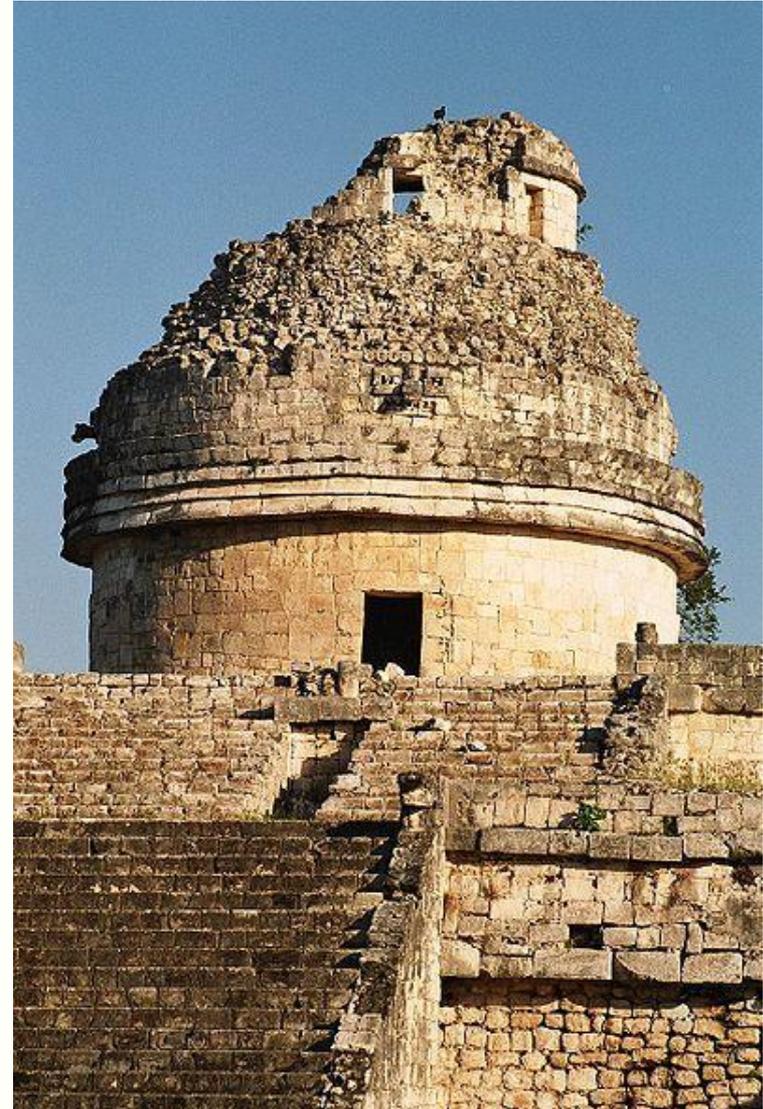
## Mayans

Outstanding *observers* of sun, stars, and moon

\*Venus was very important to them

Skilled at calendar making and *tracking* long time intervals

Only written language and mathematical system in North America



# Mayan Ruins



# Mayan City Recreation



# Astronomy impacted ancient civilizations

## Aztecs

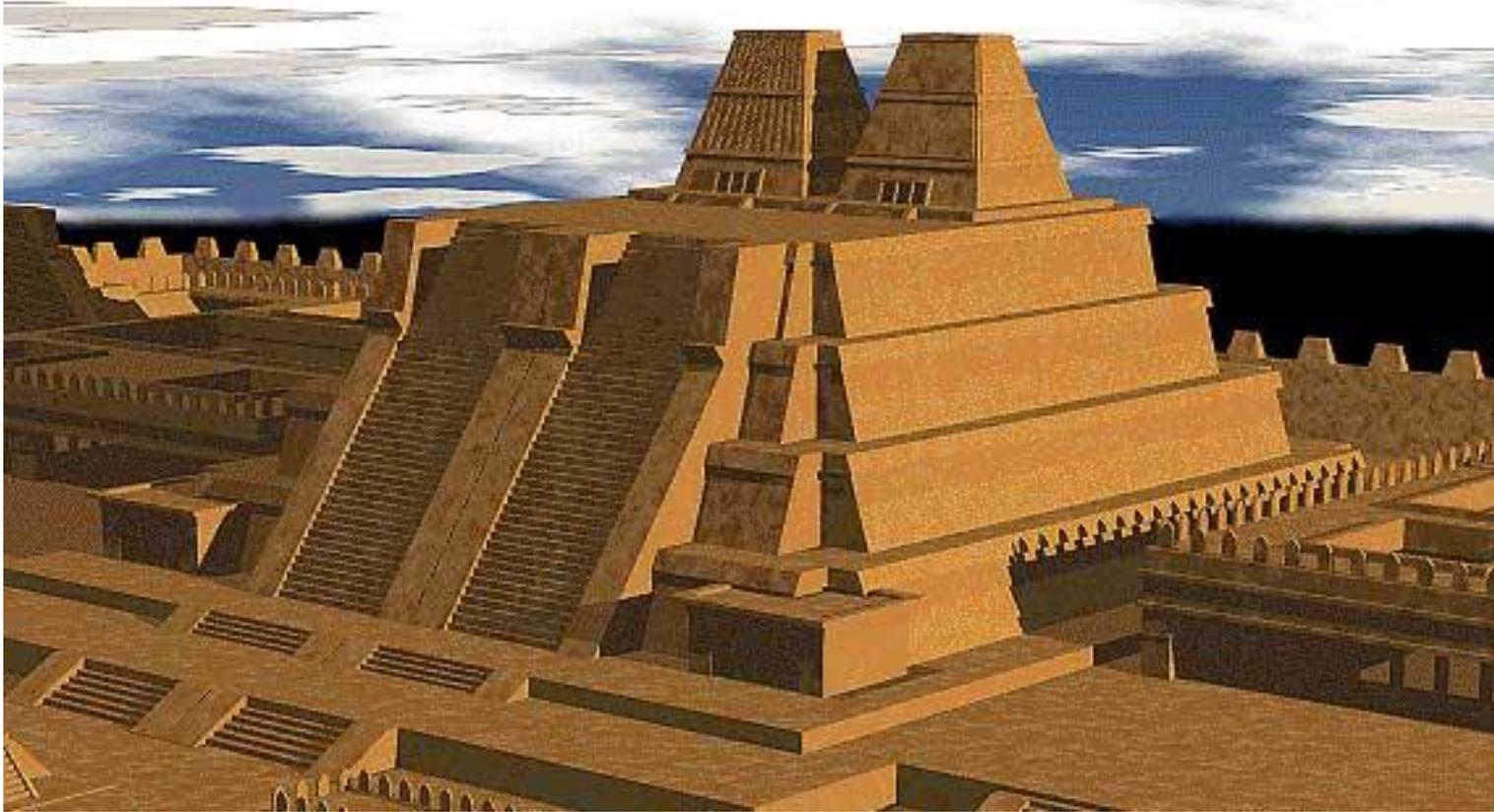


The Aztec *Sun* Calendar is a large round stone, 12 feet across weighing in at 24 tons.

The calendar was three feet thick as well, so it was not small by any means.

Calendar contained 360 days

# Aztecs





# Ancient Greek Astronomers (1)

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- Unfortunately, there are No written documents about the significance of stone and bronze age monuments.
- Greeks tried to understand the motions of the sky and describe them in terms of Mathematical (not physical!) models.

## Aristarchus (310-230 B.C.)

- 1<sup>st</sup> to place the sun at the center of the universe, but his ideas were too radical for anyone to accept.
- 1750 years BEFORE Copernicus!

## Eratosthenes (276 - 195 B.C.)

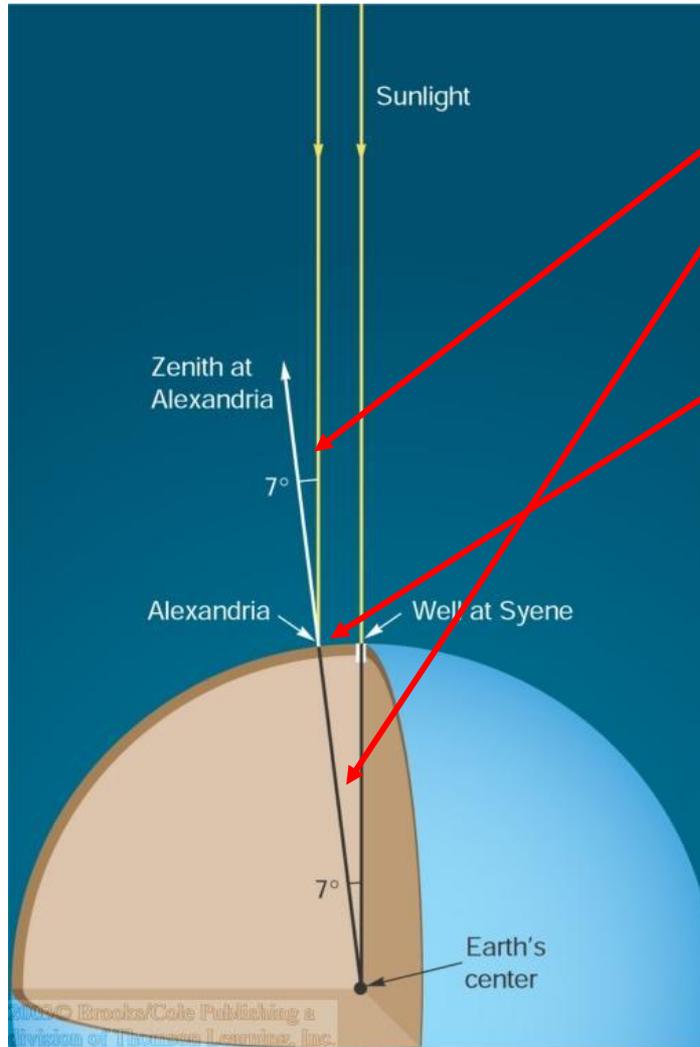
- 1<sup>st</sup> person able to measure the circumference of the Earth

## Hipparchus (190-120 B.C.)

- Compiled first star catalog
- Developed a scale for star brightness
- Accurately calculated distance from Earth to the moon!

# Eratosthenes (~ 200 B.C.):

## Calculation of the radius



Angular distance between  
Syene and Alexandria:  
 $\sim 7^\circ$

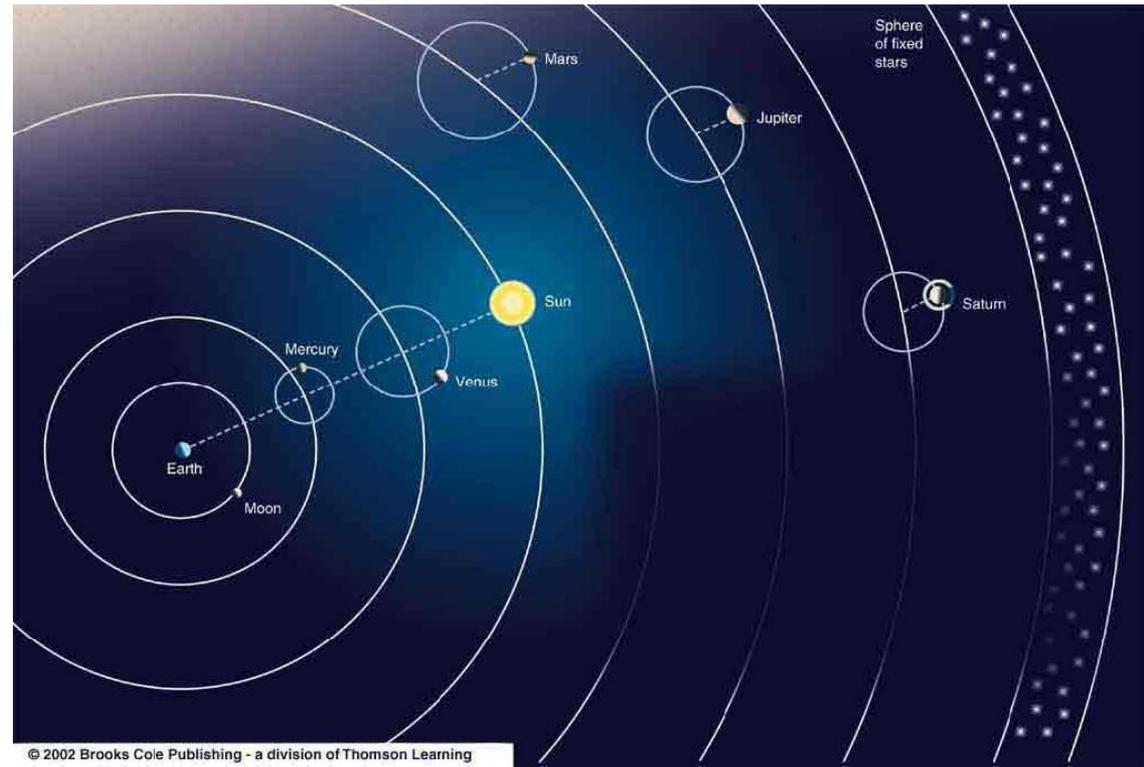
Linear distance between  
Syene and Alexandria:  
 $\sim 5,000$  stadia

→ Earth Radius  $\sim 40,000$   
stadia (probably  $\sim 14\%$   
too large) – better than  
any previous radius  
estimate.

## Ptolemy (90 – 168 AD)

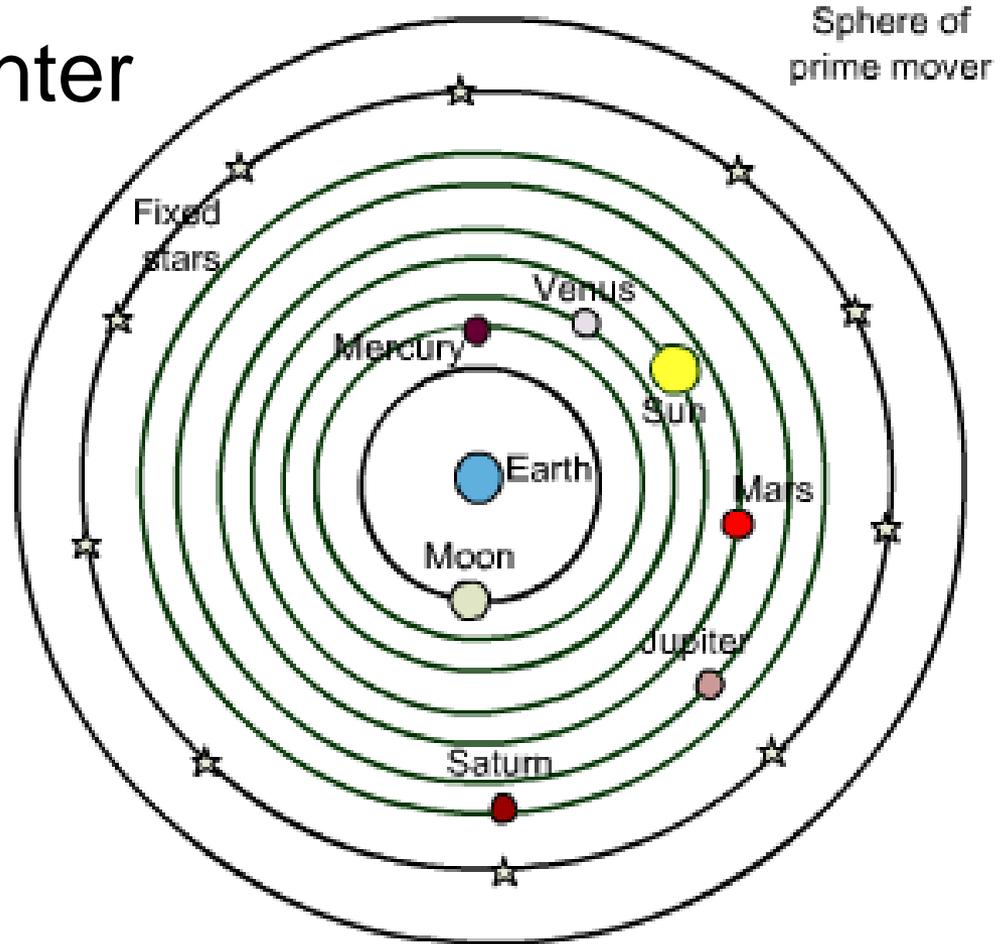
- Earth-centered model which included a complex system of Epicycles and perfect circles for the orbits of planets, sun, and moon around Earth
- Assumed that the imperfect Earth was surrounded by perfect heavenly spheres

Ptolomy's model worked so well, it was not challenged for 1300 years!



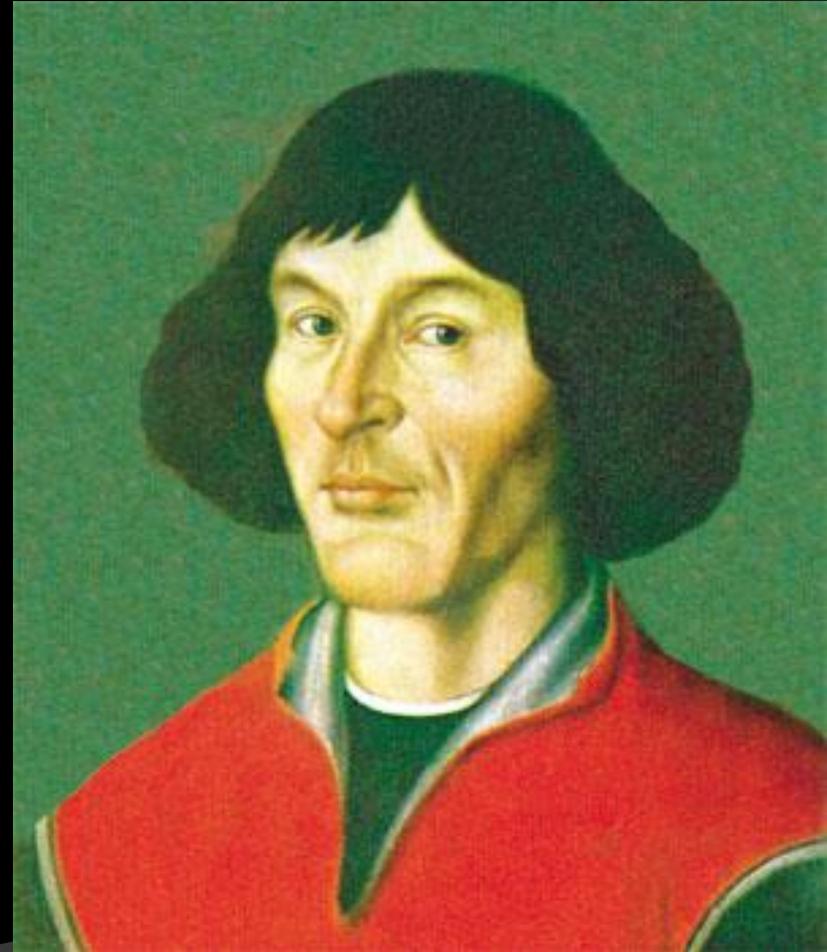
# Prevailing Theory

- Earth was the center
- of the universe



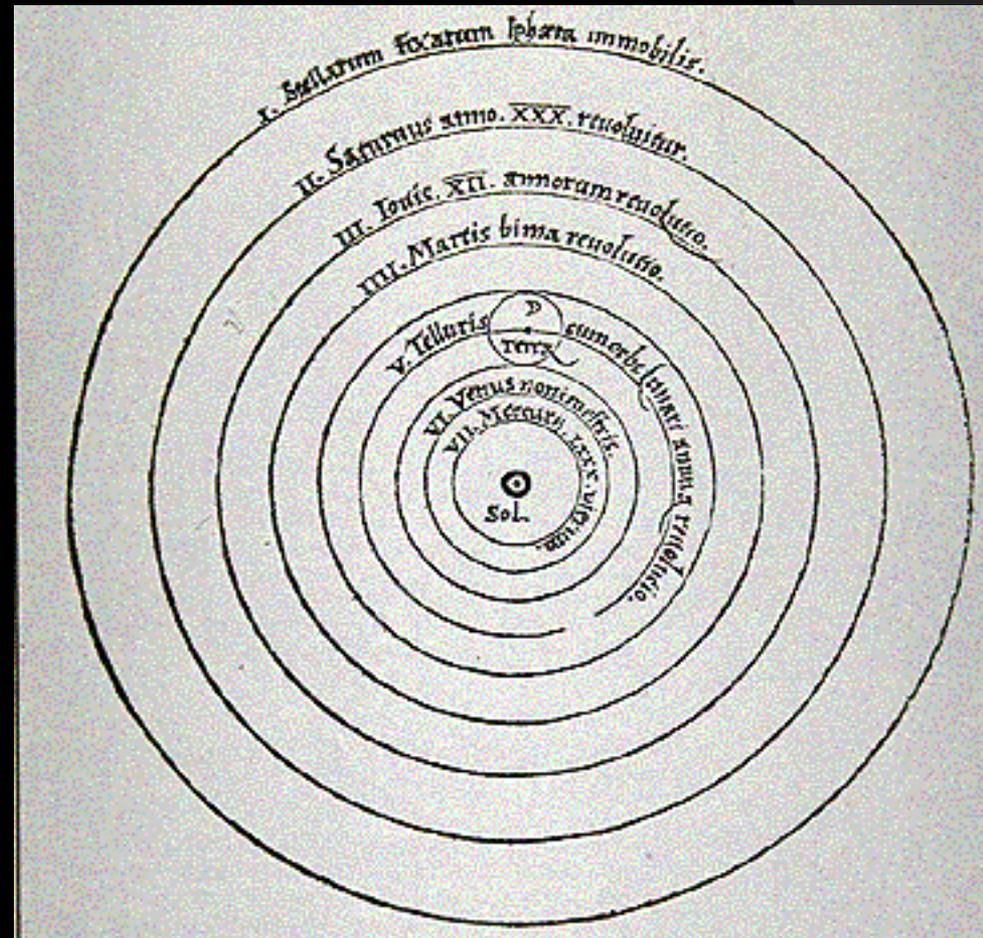
# Copernicus (1473-1543, Poland)

- Popularized the sun-centered, “heliocentric” model of universe
- Stated that the earth spins once per day on its axis and revolves around the sun in one year
- Published in *Des Revolutionibus* in 1543 (on his death bed)



# The Heliocentric Model

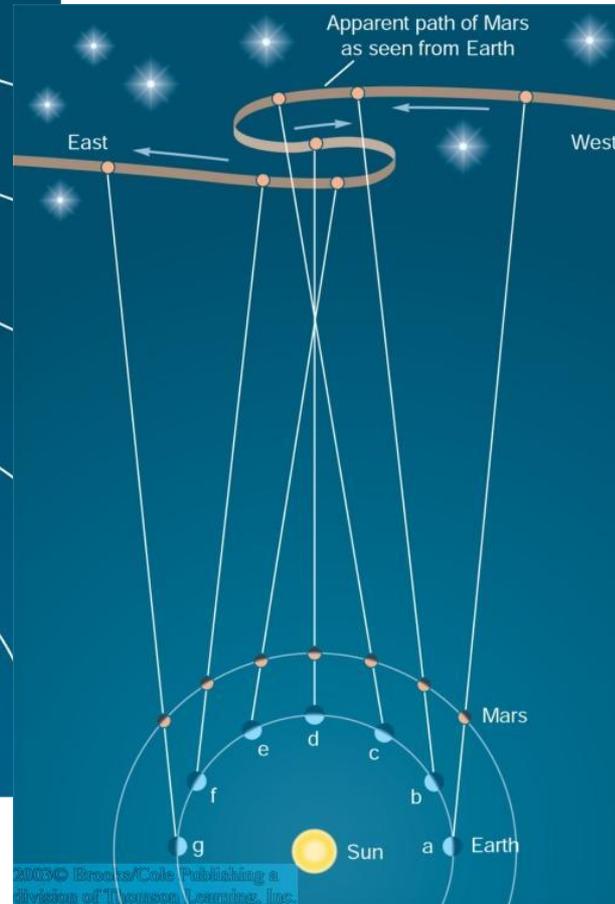
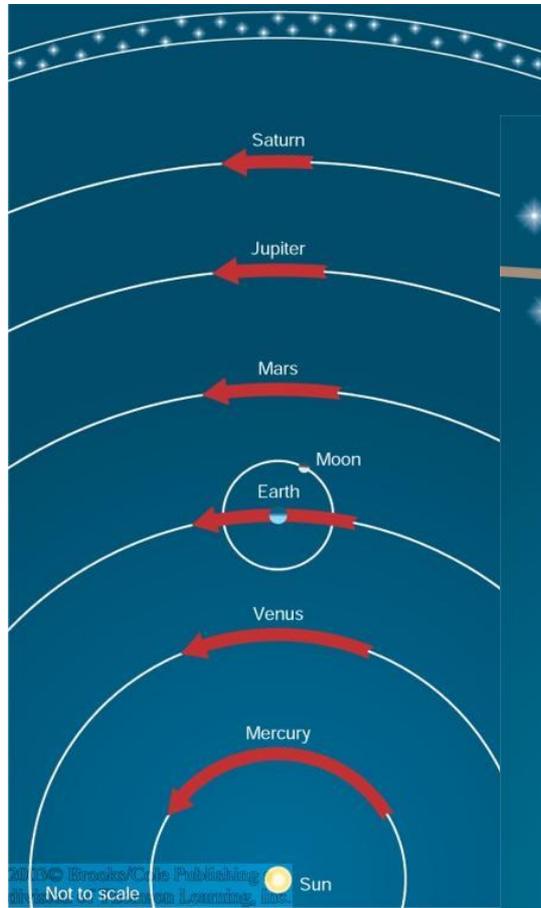
- Sun at center of universe
- Planets orbit sun in perfect circles
- Stars on a huge fixed sphere (the firmament)



# More Copernicus

- Explained retrograde motion using passing orbits
- Correctly ordered planets, and calculated their distances!
- Correctly calculated time for planets to orbit sun
- Explained apparent motion of stars and sun using Earth's rotation and orbit
- Explained why Mercury and Venus are always seen near the Sun
- Invented idea of Astronomical Unit (A.U.) – Distance of Earth from the Sun (About 93 million miles)

# Copernicus' new (and correct) explanation for retrograde motion of the planets

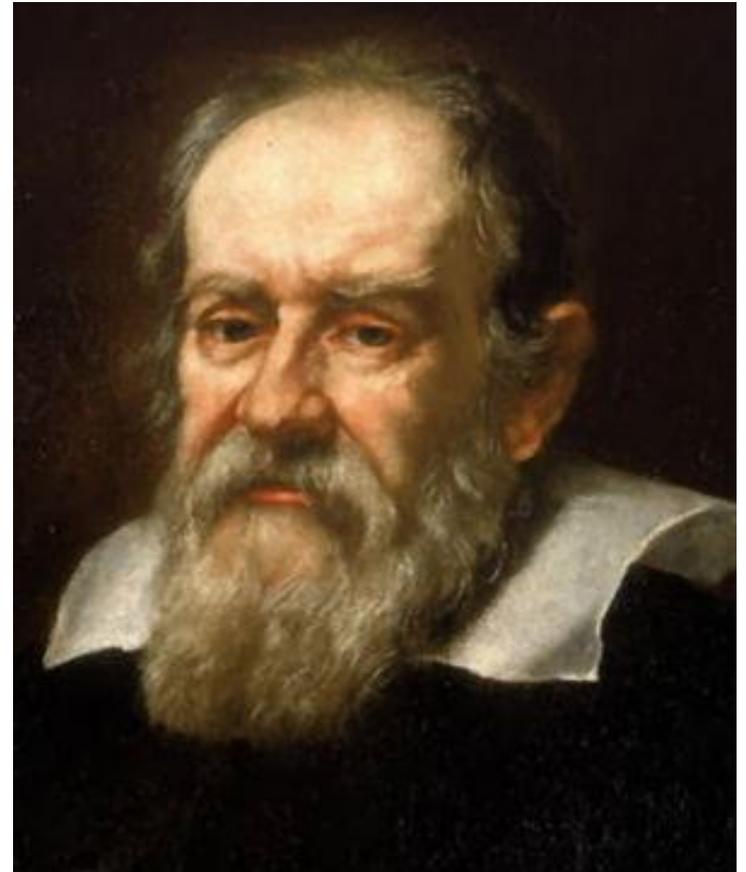


Retrograde (westward) motion of a planet occurs when the Earth *passes* the planet.

This made Ptolemy's epicycles unnecessary.

## Galileo Galilei (1564–1642, Italy)

- Father of observational astronomy
- 1<sup>st</sup> to publish in Italian...Not Latin!
- While he did not invent the telescope, he was the first to use the telescope for astronomy



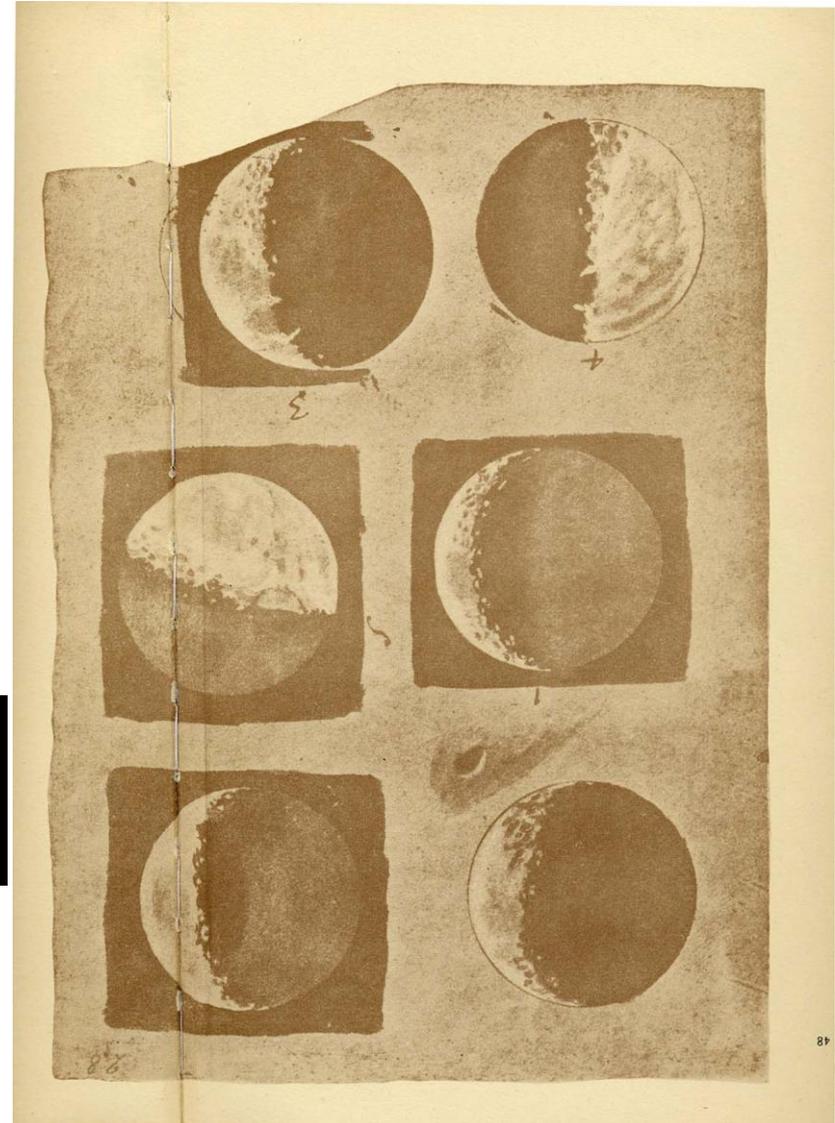
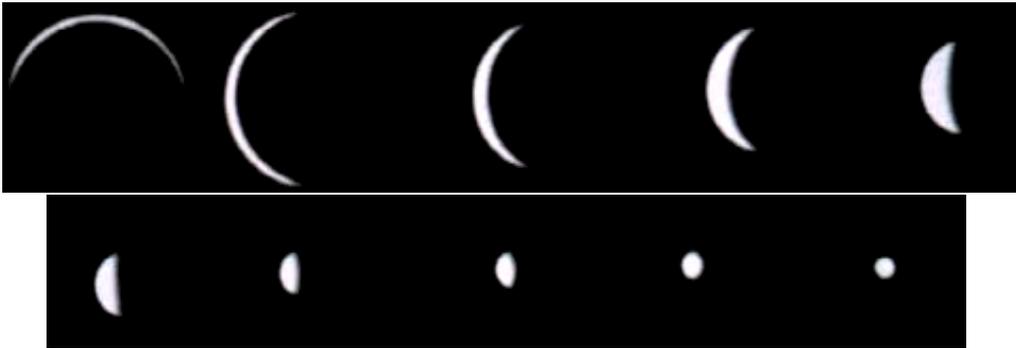
# Galileo's Astronomical Accomplishments

- Redesigned the telescope to be suited for observing the sky (only 14X magnification)
- Discovered that there were many stars not visible to the naked eye



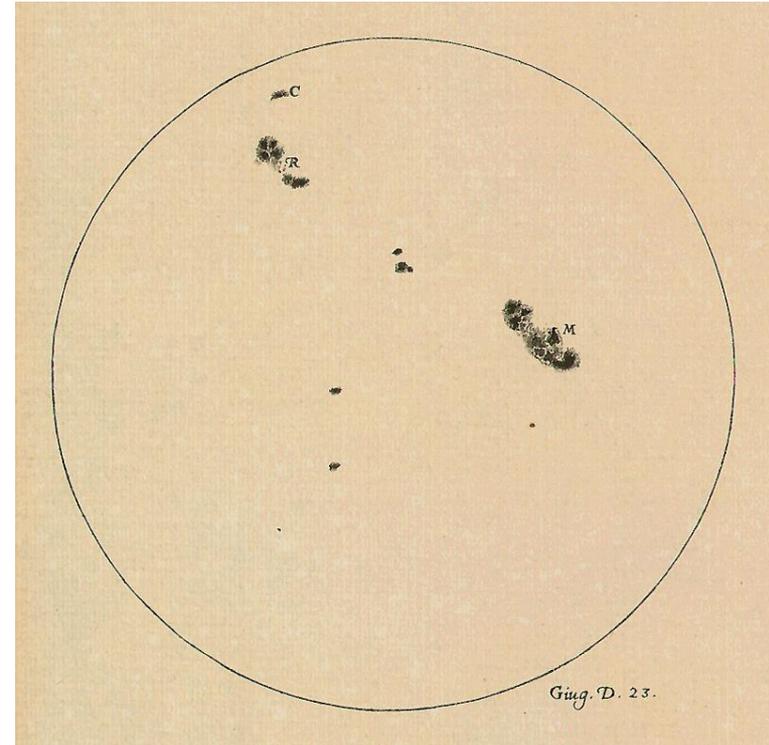
## More Galileo

- Discovered mountains, craters, and plains on Moon
- Discovered phases of Venus similar to the moon



## And More Galileo

- Discovered sunspots on Sun



# Still More Galileo

- Discovered 4 moons orbiting Jupiter

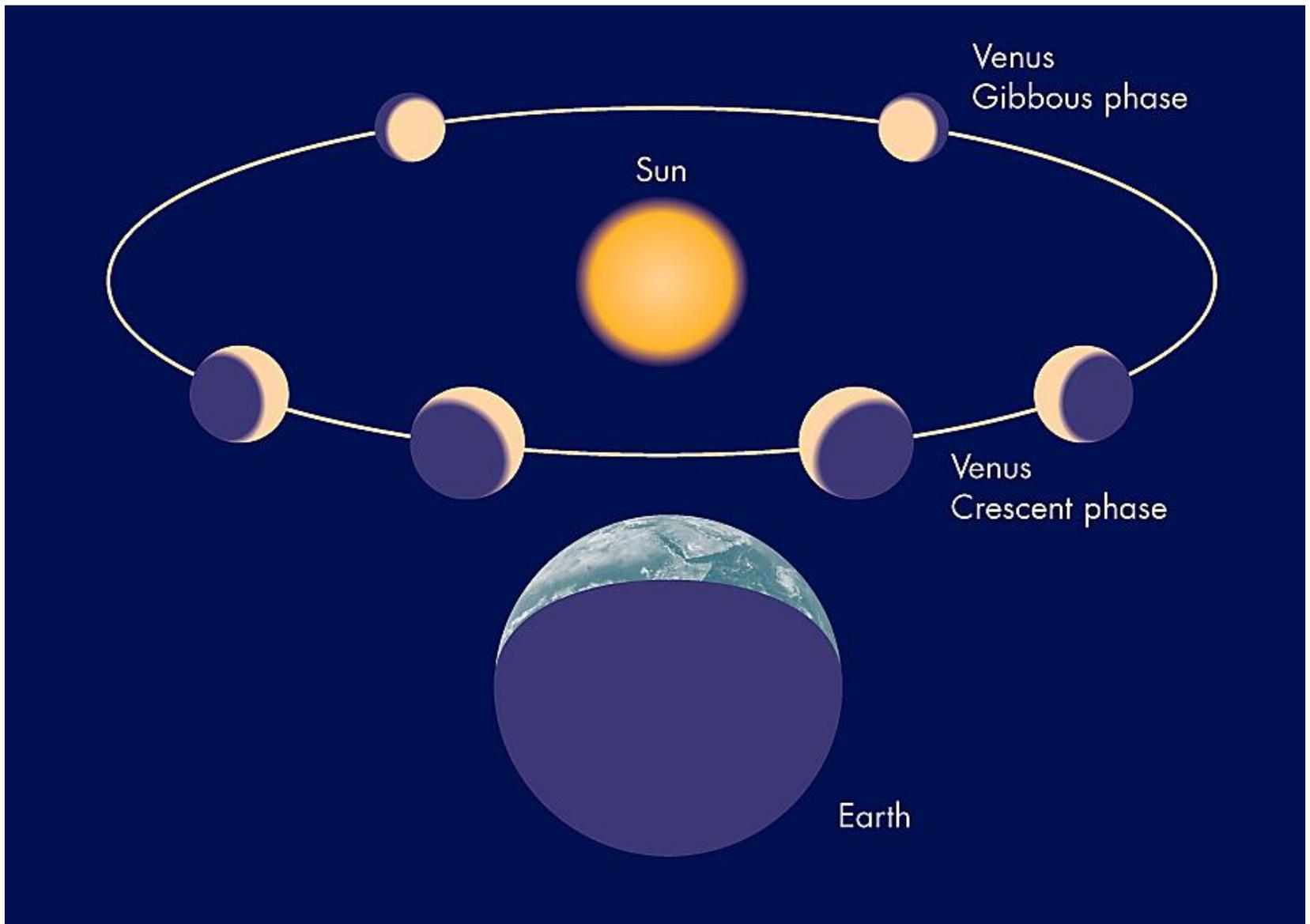


*Observations Perseus  
1610*

<i>2. J. 12. 12</i>	<i>○ **</i>			
<i>30. mare</i>	<i>** ○ *</i>			
<i>2. 26. 12</i>	<i>○ ** *</i>			
<i>3. mare</i>	<i>○ * *</i>			
<i>3. Ho. 5.</i>	<i>* ○ *</i>			
<i>7. mare</i>	<i>* ○ **</i>			
<i>6. mare</i>	<i>** ○ *</i>			
<i>8. mare H. 13.</i>	<i>* * * ○</i>			
<i>10. mare</i>	<i>* * * ○ *</i>			
<i>11.</i>	<i>* * ○ *</i>			
<i>12. H. 4. 2. 12</i>	<i>* ○ *</i>			
<i>13. mare</i>	<i>* ** ○ *</i>			
<i>14. mare</i>	<i>* * * ○ *</i>			

# Progress at Personal Cost

- Placed under house arrest by Catholic Church and made to confess “vainglorious ambition” and mistakes of “pure ignorance” (aka – renounce Copernicanism)
- Not all religious: some political and personal rivalries, too
- Worked on laws of motion and falling bodies until his death (8 years later)



**Phases of Venus....Evidence for a Heliocentric Solar system**

# Tycho Brahe (Teeko Bra-hay) (1546 - 1601)

- A Danish nobleman
- Believed in geocentric model of solar system
- designed and built accurate and powerful instruments to observe the stars
- used these instruments to chart the positions of planets and other celestial objects with great precision
- disproved many of the commonly held notions of planetary and stellar motion
- Difficult to work with. He wasn't very nice :-\
- Died of a burst bladder (yukko!)

# Contributing Scientists

## Kepler

Pure theorist, used mathematical principles to predict planetary orbits

He based his work almost entirely on the observations of another scientist

Devised laws of *planetary* motion



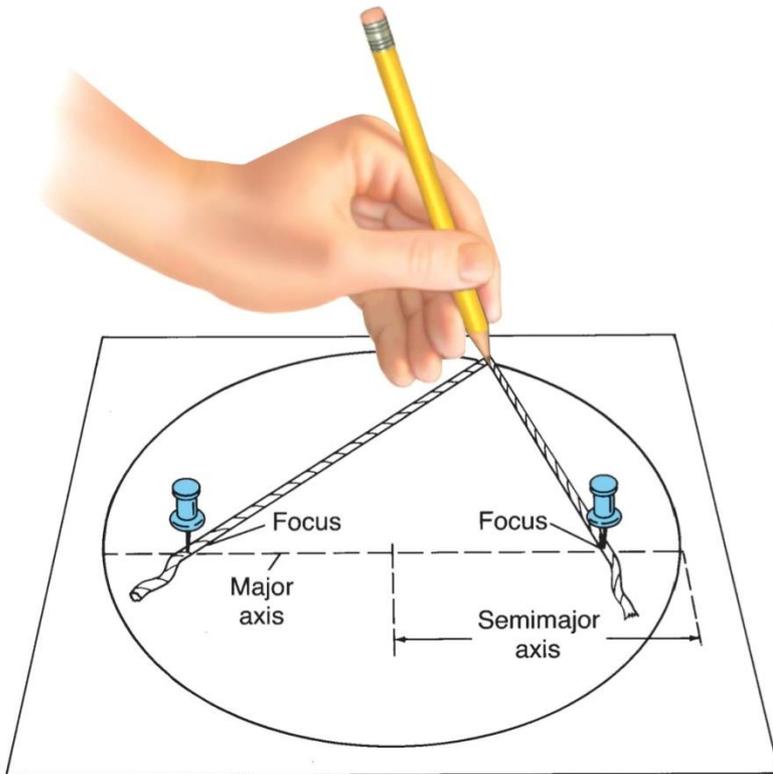
# Contributing Scientists

## Kepler

**Kepler's First Law** has to do with the *shapes* of the planetary orbits:

The orbital paths of the planets are *elliptical* (not necessarily circular).

Two of the most important points of orbit are the planet's perihelion (its point of closest approach to the Sun) and its aphelion (greatest distance from the Sun).

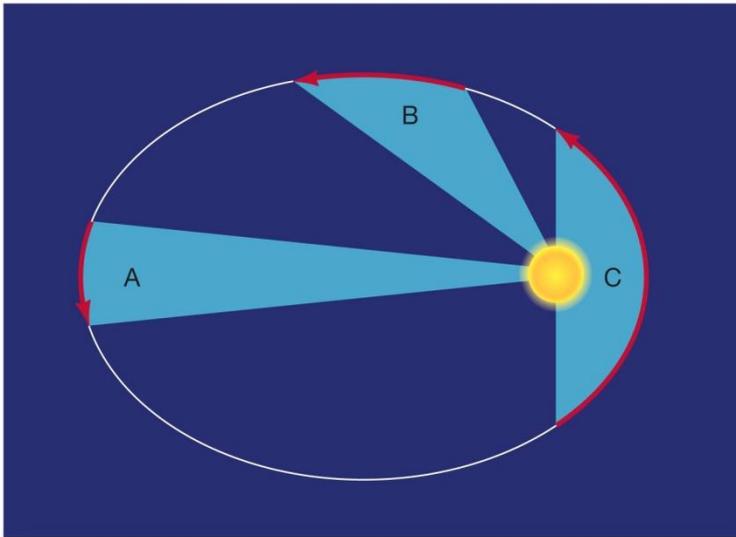


# Contributing Scientists

## Kepler

**Kepler's Second Law** addresses the *speed* at which a planet traverses different parts of its orbit:

An imaginary line connecting the Sun to any planet sweeps out *equal* areas of the ellipse in equal intervals of time.

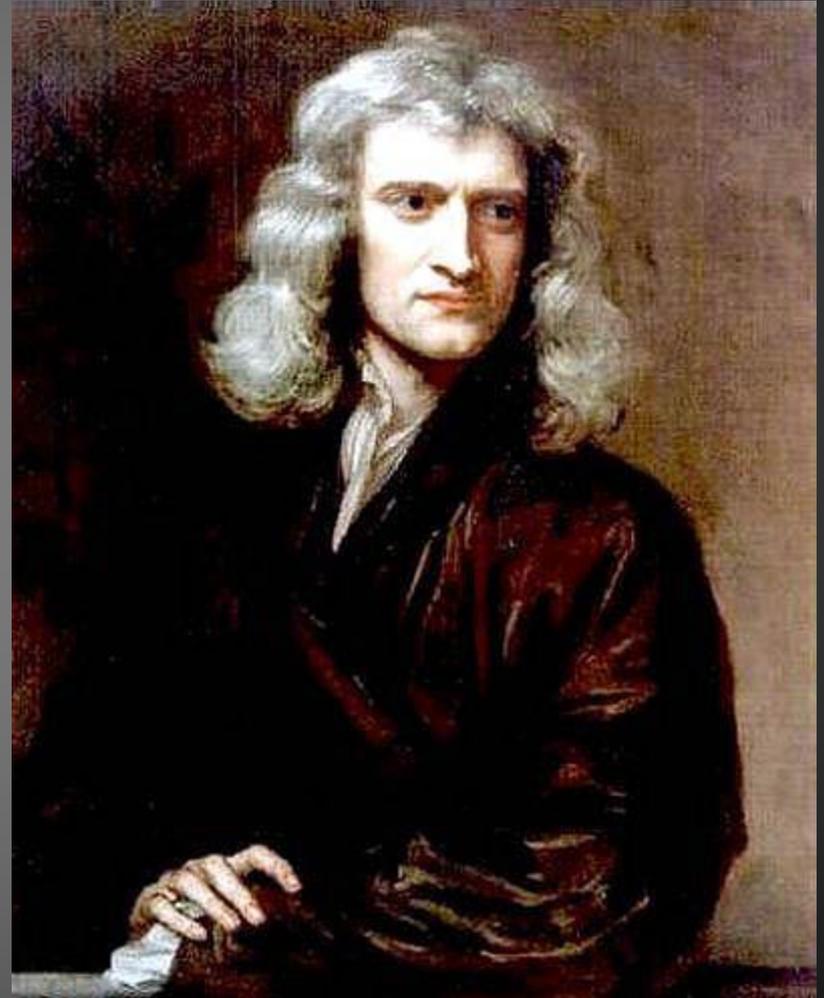


$$P_y^2 = a_{AU}^3$$

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

# Isaac Newton (1642-1727, England)

- Not expected to live over a few hours...instead lived 84 years and 3 months
- Served as England's "Master of the Mint"
- Knighted in 1705



# Newton's Contributions

- *Invented* calculus (at age 23!)
- Realized that “white light” can be broken down into colors of rainbow using a prism (age 30)
- Invented reflecting (mirror-based) telescope, a great improvement over Galileo's refracting (lens-based) telescope

# More Newton

- Mathematically derived Kepler's 3 Laws.
- Calculated the existence of other planets due to orbital anomalies of outer known planets
- Law of Universal Gravitation:
  - Gravity exists between any 2 objects that have mass
  - Gravity is always attractive, never repulsive
  - Gravity increases with increasing mass
  - Gravity decreases with increasing distance
- 3 Laws of Motion

# Historical Overview

