When Astronomy was Astrology

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ONU 2009

Outline

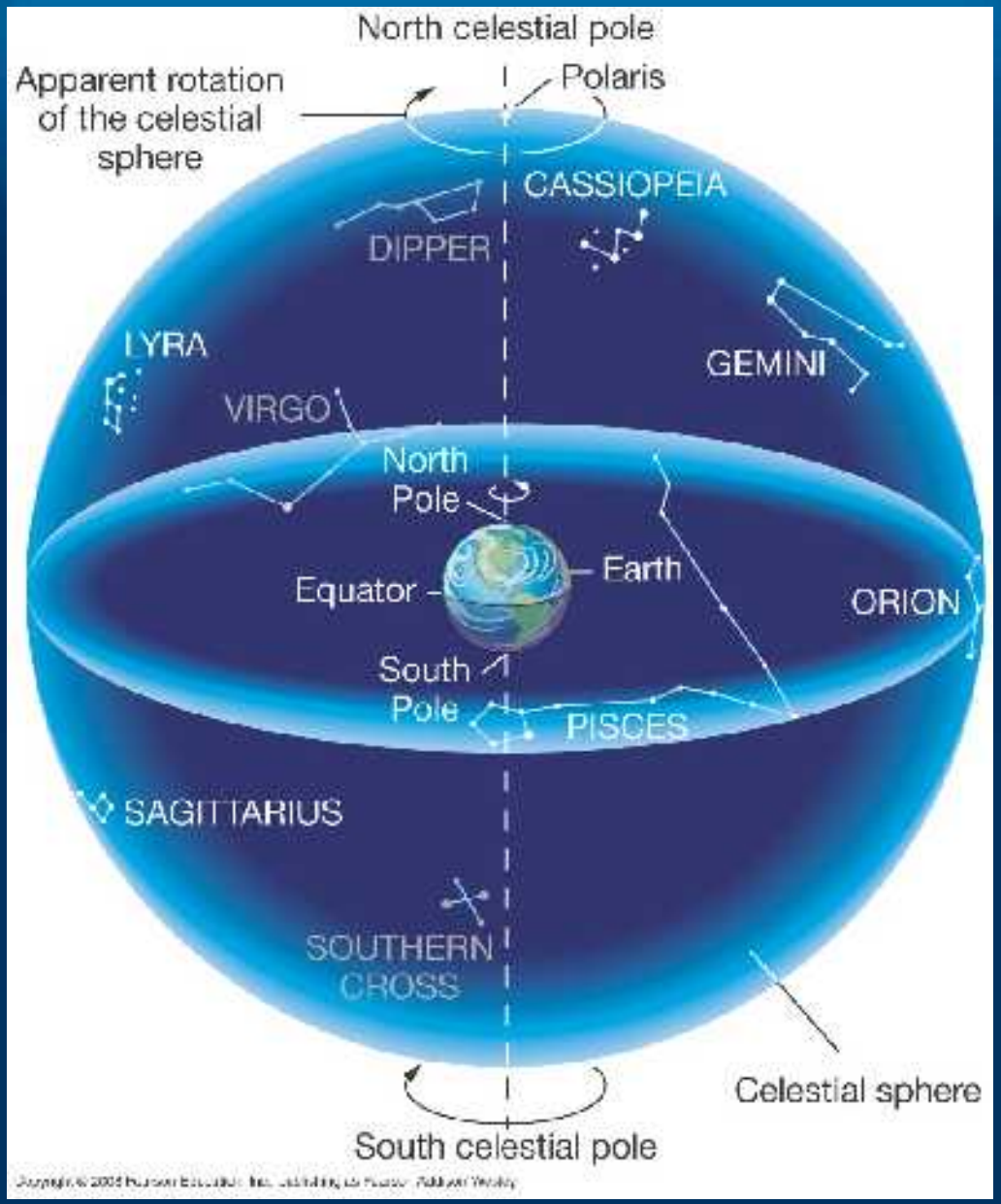
- What the ancients could see
- What the ancients knew – archaeological evidence
- What the ancients believed
- Greek cosmological models
  - *The Ptolemaic Geocentric Solar System*

What the Ancients Could See

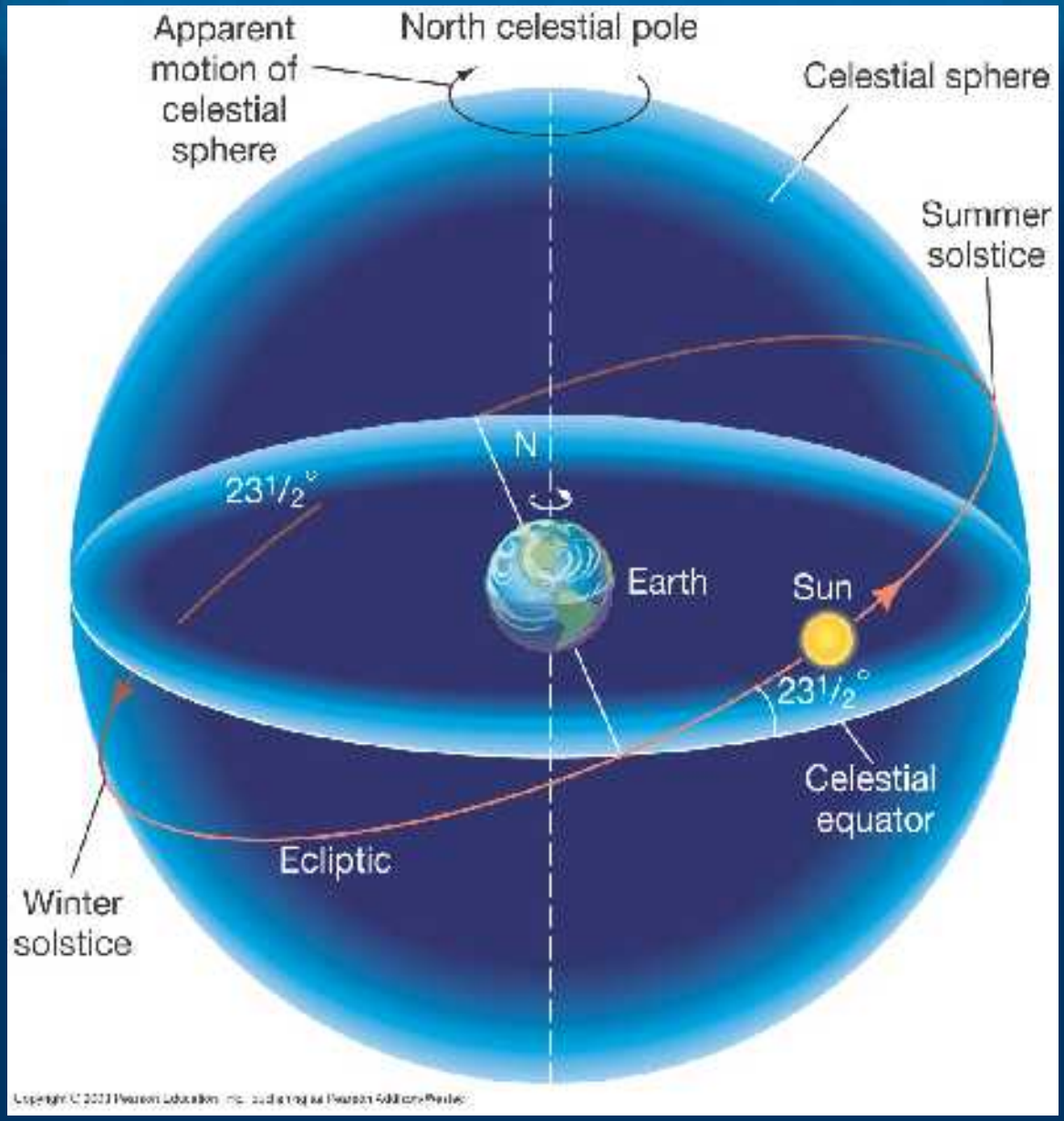
The Naked-Eye Universe

- The Sun (daily motion and annual motion)
- The Moon (phases, eclipses)
- 5 Planets (not including the Earth)
  - Mercury, Venus, Mars, Jupiter, Saturn
- 6500 Stars (contained within 88 constellations)
- 3 galaxies
- Occasional novae and supernovae
- Comets
- Aurora, meteors, and other atmospheric phenomena

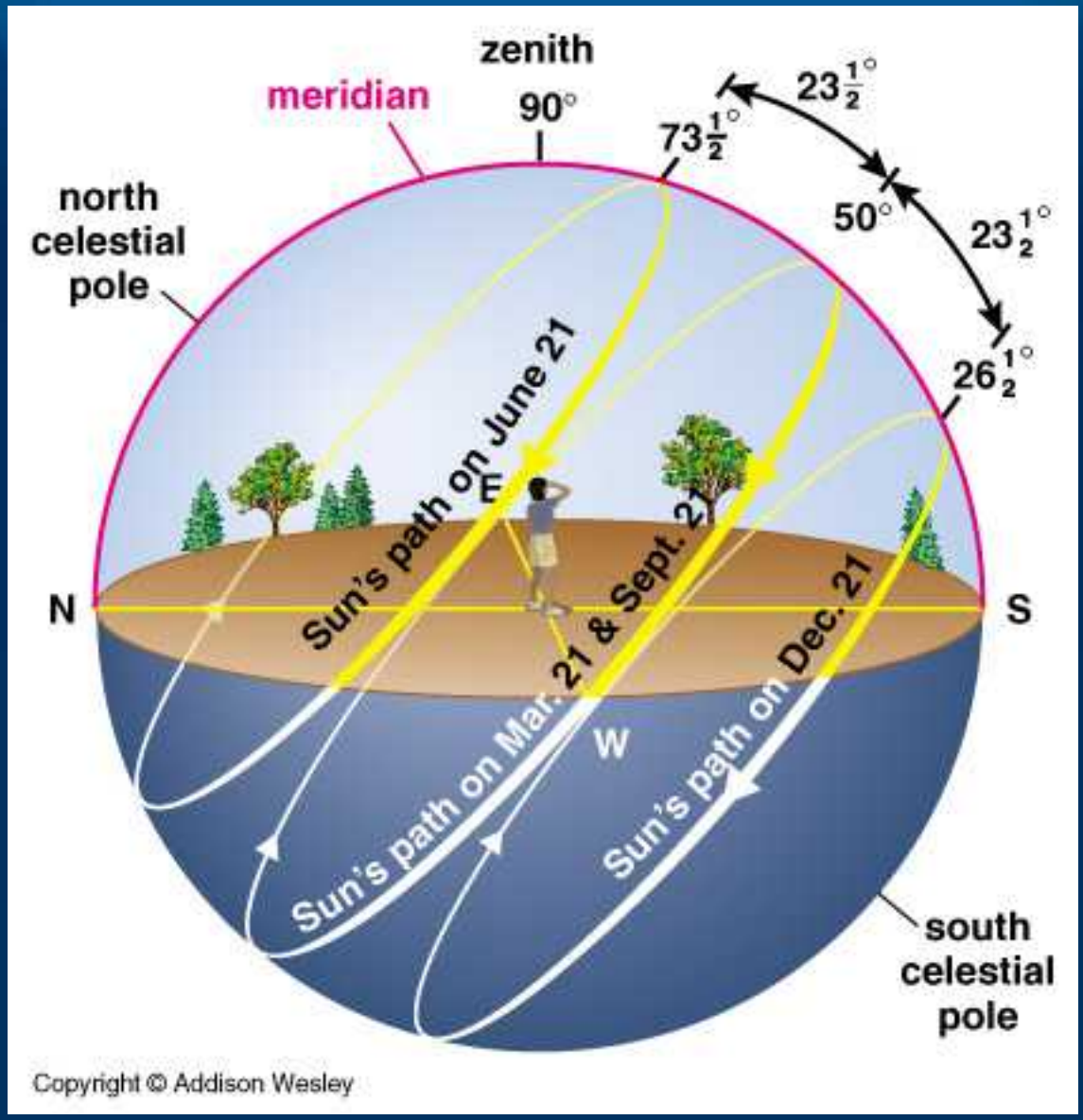
The Celestial Sphere



Celestial Sphere and the ecliptic



Solstices and Equinoxes



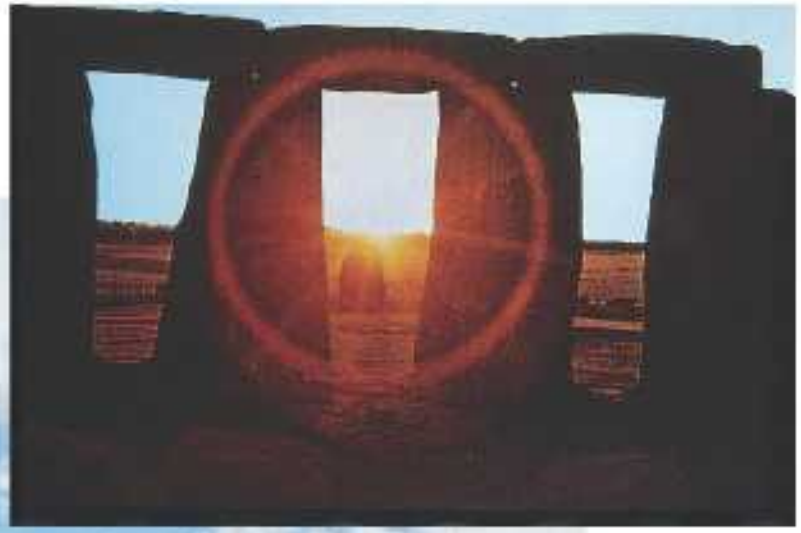
What the Ancients Knew

- Mysterious cultures
  - British Isles people of Stonehenge
  - Native Americans - Plains Indians, Anasazi
  - ►left behind calendar-like constructions.
- More well-documented cultures
  - Sumerian, Babylonian, Egyptian, Arab, Greek
  - ►left records of lunar cycles, eclipses, comets, novae, star maps, models

The Ancients: *Stonehenge*

- Check out: http://witcombe.sbc.edu/earthmysteries/EMStonehenge.html
- 2950 BC – 1600 BC (3 phases)

- 30 Y-holes, 28 Z-holes, 56 Aubrey holes = 3 Lunar Standstills (18.6 yrs)
- Heel stone marks sunrise on Summer Solstice



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The Ancients: *Newgrange*, Ireland

Megalithic passage tomb. 3200 BC

(a)

(b)

(c)

The Plains Indians – Big Horn
The Mayans – Caracol in Chichen Itza
The Anassazi/Pueblo – Chaco Canyon

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What the Ancients Knew

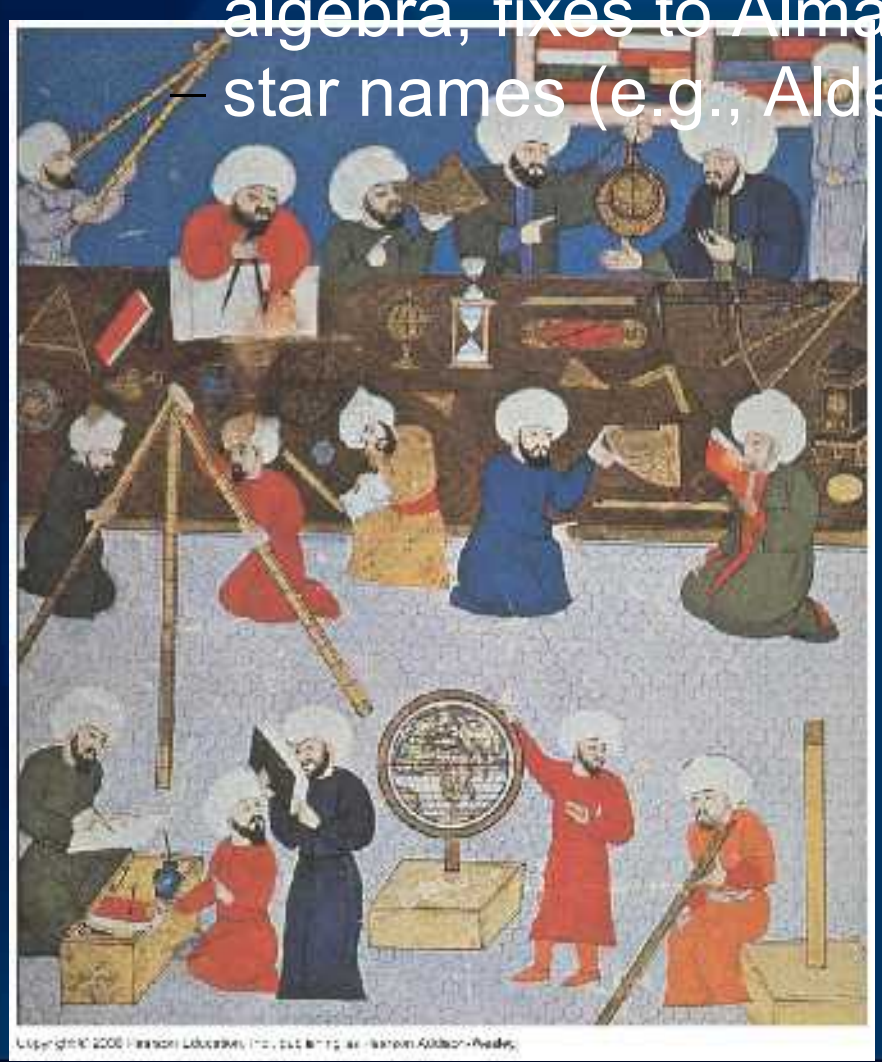
- Pre-Greek cultures
  - Sumerians (c. 3000 BC): first astronomers, ziggurats, zodiacal constellations, number system based on 60, clocks, 12 mo. lunar calendar with leap months,
  - Babylonians: origin of western astrology, observations correlated to events, math, Saros cycle of Moon.

What the Ancients Knew

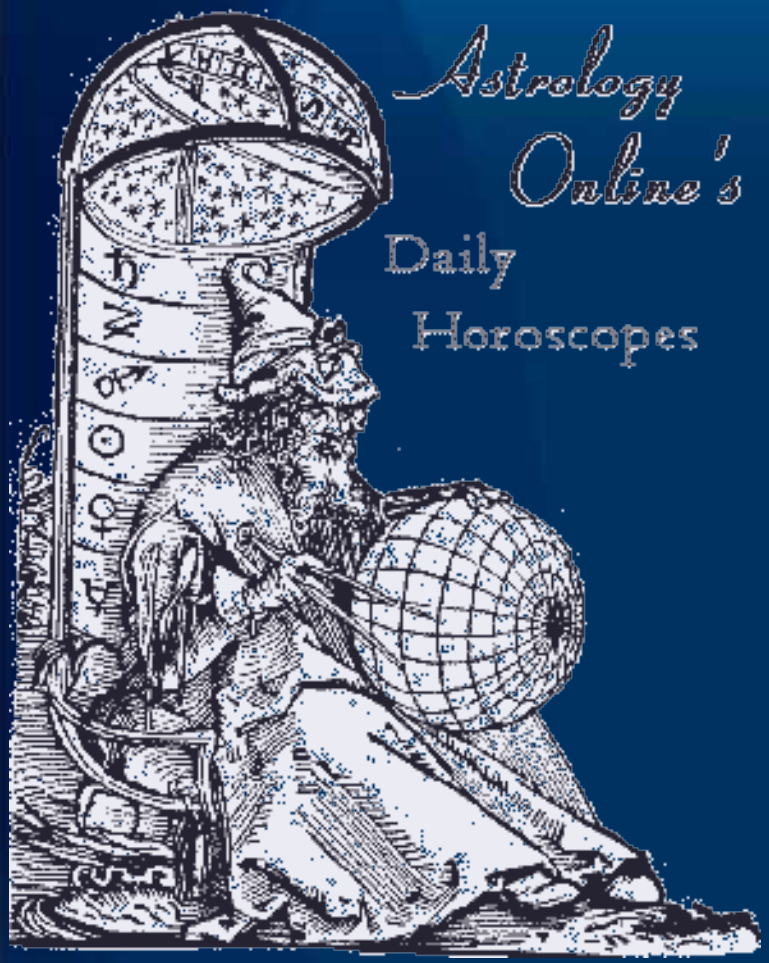
- Pre-Greek cultures: Egyptian
  - Calendar – 12, 30 day months, no leap year!
  - pyramids, Abu Symbel
  - constellations
  - gods like Re=Sun, Nut=sky, and Osiris=Orion
  - Sirius and the Nile flooding

What the Ancients Knew

- Well documented cultures
  - Arabs: upheld astronomy during dark ages, algebra, fixes to Almagest, new observations,
  - star names (e.g., Aldebaran, Vega).



What the Ancients Believed

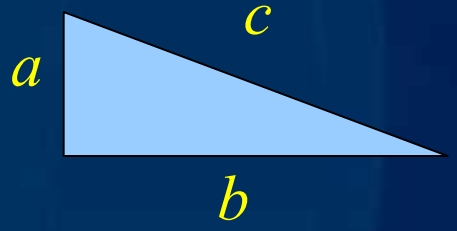


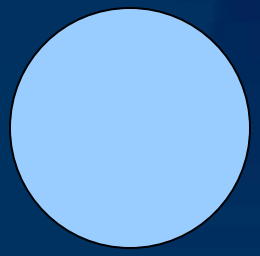
- Sumerians & Babylonians
  - creation myth (Enuma Elish), stars as spirits, astrology
- Egyptians - polytheism
- Persian/Arab
  - Semantic distinction between astronomy and astrology – 1000 AD!
  - ► All had forms of astrology

Unknown nature → superstition → astrology.

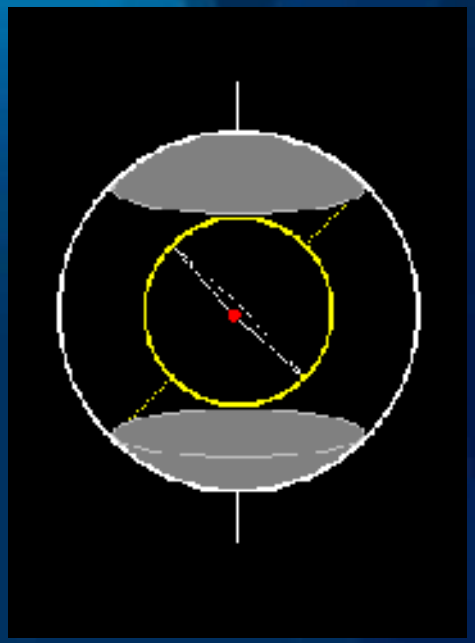
Knowledge of the Ancient Greeks I.

- Ideas and philosophies were rich and varied, some correct and some incorrect.
  - Thales of Miletus (b. 624-547 BC):
    - universe is rational
    - predicted eclipse ~585 BC
  - Pythagoras (570-497 BC):
    - math inherent in nature
    - Earth and planets are spherical
  - Plato (428-347 BC):
    - Truth through pure thought over observations
    - Circle is most perfect form





Knowledge of the Ancient Greeks II.



- Eudoxes of Cnidus (390-337 BC):
  - Nested (crystalline) sphere model

- Aristotle (384-322 BC):
  - Earth is unmoving, heavens are perfect
  - Everything made of 4 elements: earth, water, wind, fire
  - If Earth rotated, we'd feel a wind
  - Phases of the Moon
  - If Earth revolved, the stars should exhibit parallax

Knowledge of the Ancient Greeks (cont.)

Parallax = the apparent motion or shifting of an object caused by the motion or shifting of the observer.

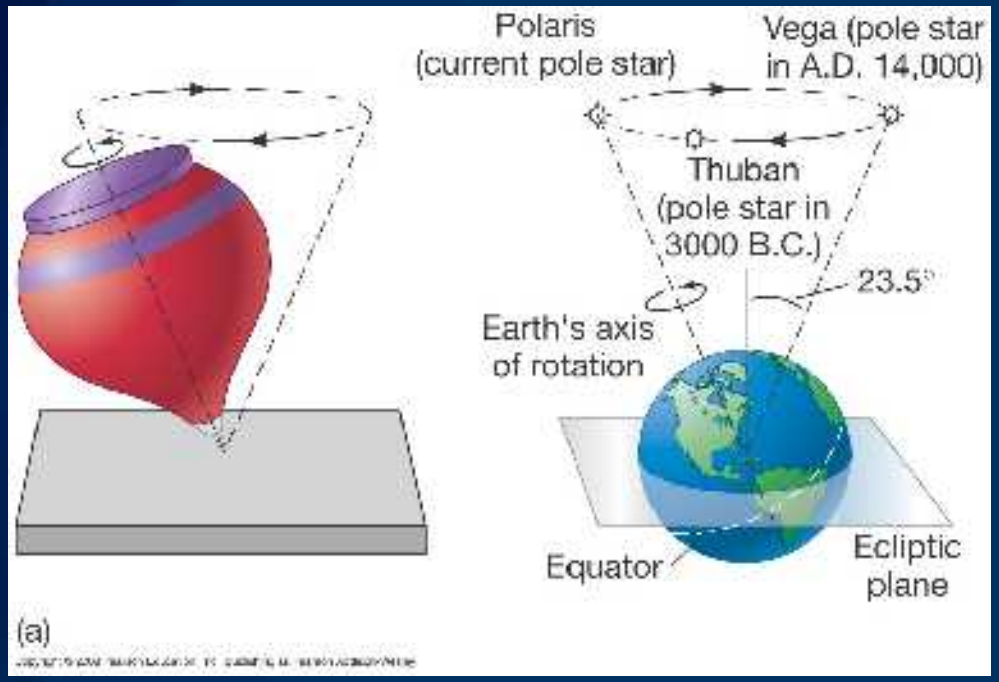
Stellar parallax – apparent motion of foreground stars due to Earth's orbital motion. (Typically <~ 0.1", biggest ~1.0" Proxima Cen.)

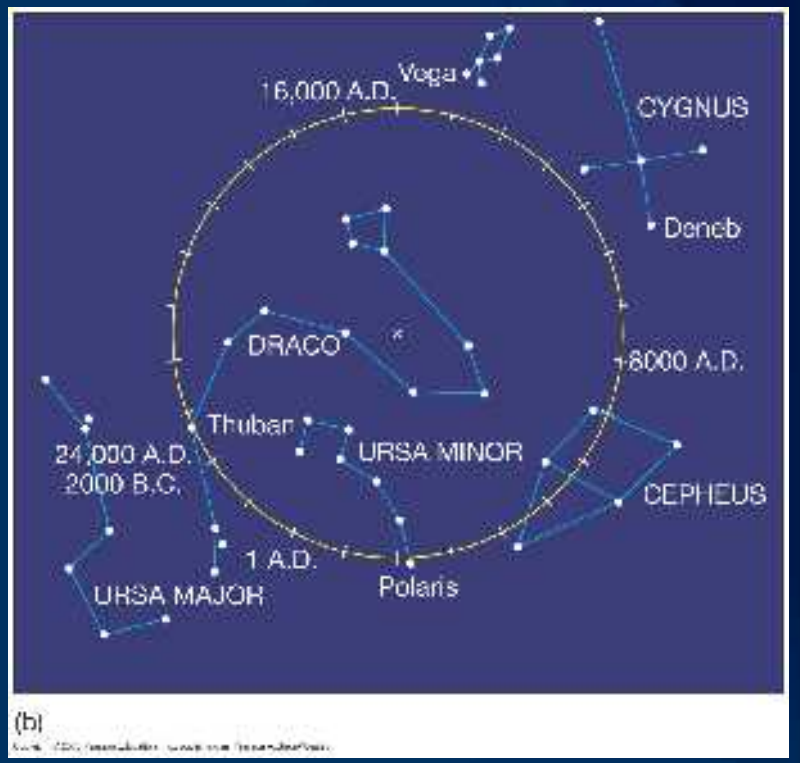
Knowledge of the Ancient Greeks III

- Philolaus (480-385 BC)
  - Earth in motion around invisible “fire”
- Aristarchus (310-230 BC)
  - The Earth orbits around the Sun (!)
- Eratosthenes (276-195 BC)
  - Measured circumference of the Earth.
- Hipparchus (190-120 BC)
  - Discovered precession of Earth's spin axis
  - Uses epicycles, deferents and eccentrics in modeling motion of Sun and Moon.
  - Invents armillary sphere

Knowledge of the Ancient Greeks (cont.)

Earth's spin axis precesses with 26,000 yr period - *(Hipparchus 160-127 BC)*.





Knowledge of the Ancient Greeks IV

- Claudius Ptolemy (AD 83-168)
  - Geocentric universe model
  - Adopts Hipparchus' epicycles to reproduce retrograde motion of planets
  - Added equants to better match speeds of planets
  - Writings on Optics, Geography, Music
  - Astronomy: “Mathematike Syntaxis” = “The Almagest”
  - Astrology: “Tetrabiblios” relates horoscopes to Aristotelian philosophy

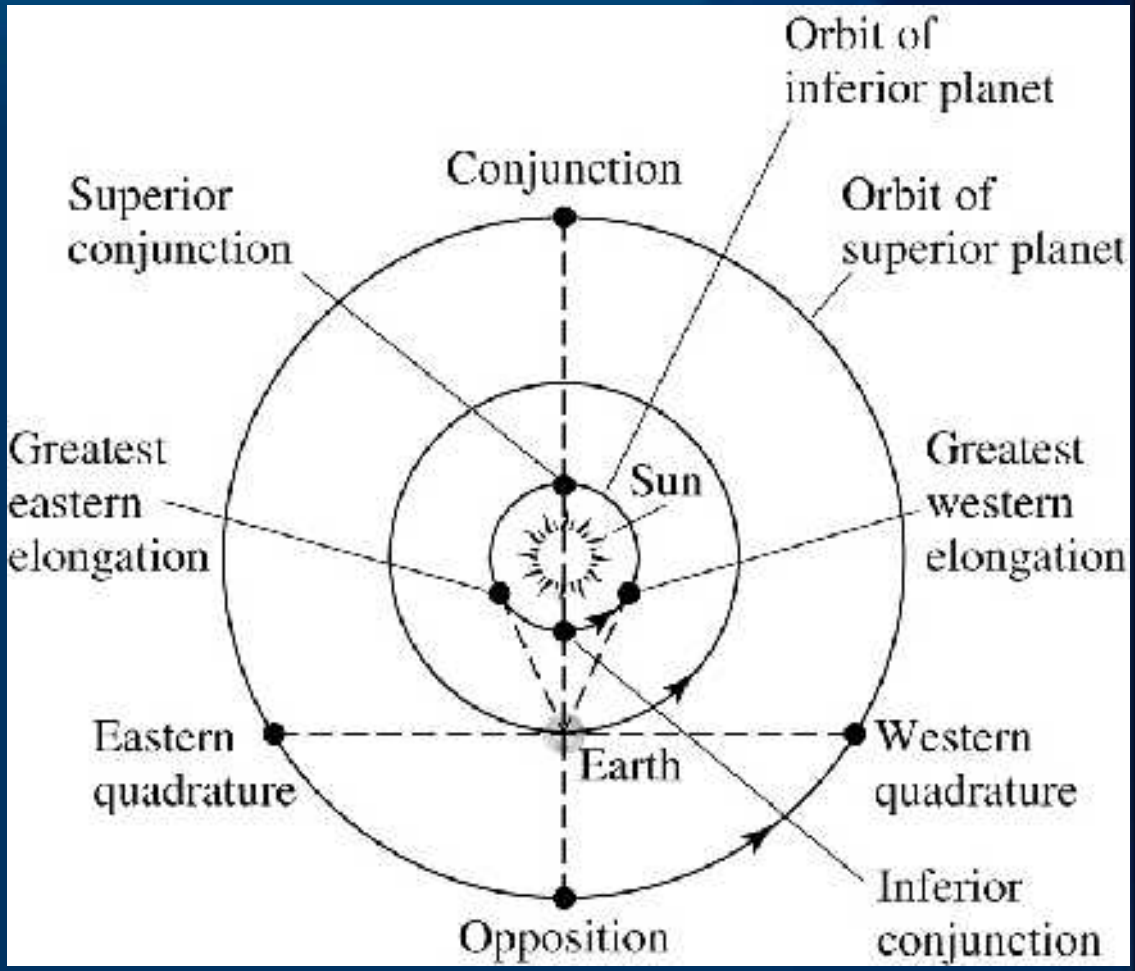
The Appearance of the Planets

- Daily motion
- Change brightness, position and angular speed across sky.
- All orbit CCW as seen from “North”.
- Usually eastward motion, occasional westward motion we call ...

Retrograde Motion!

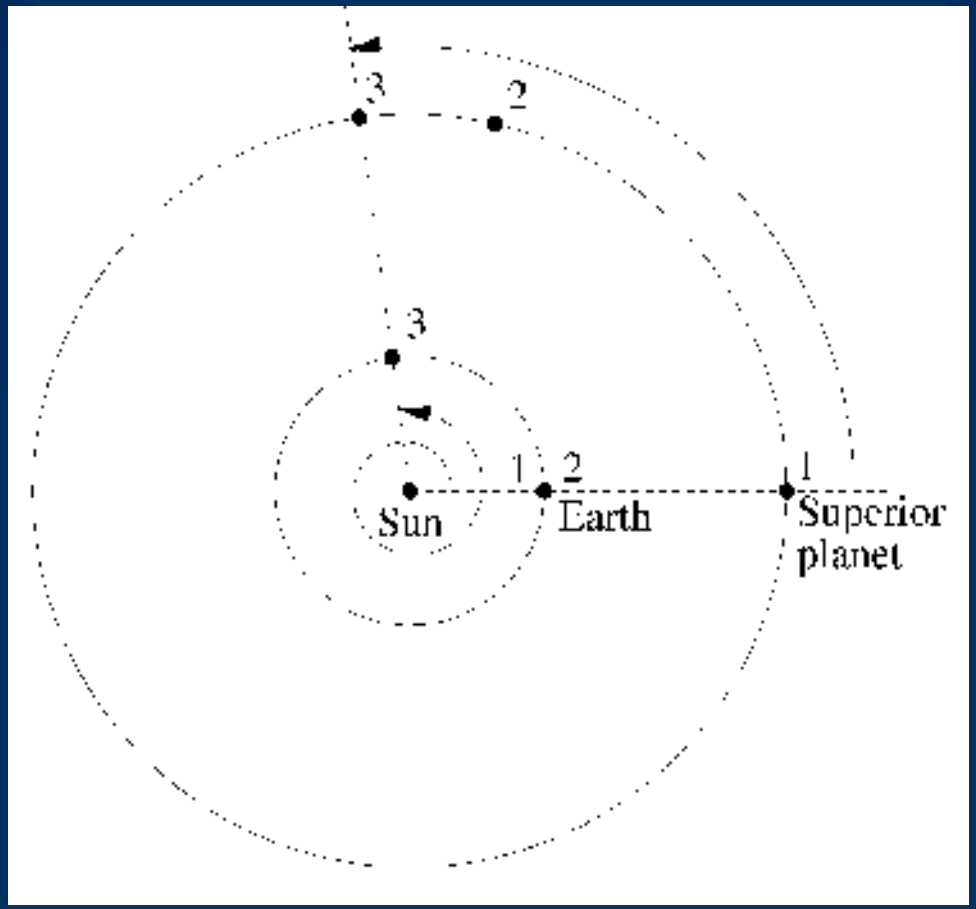
Planetary Configurations

- Inferior planets
  - Two conjunctions
- Superior planets
  - One conjunction
  - Opposition



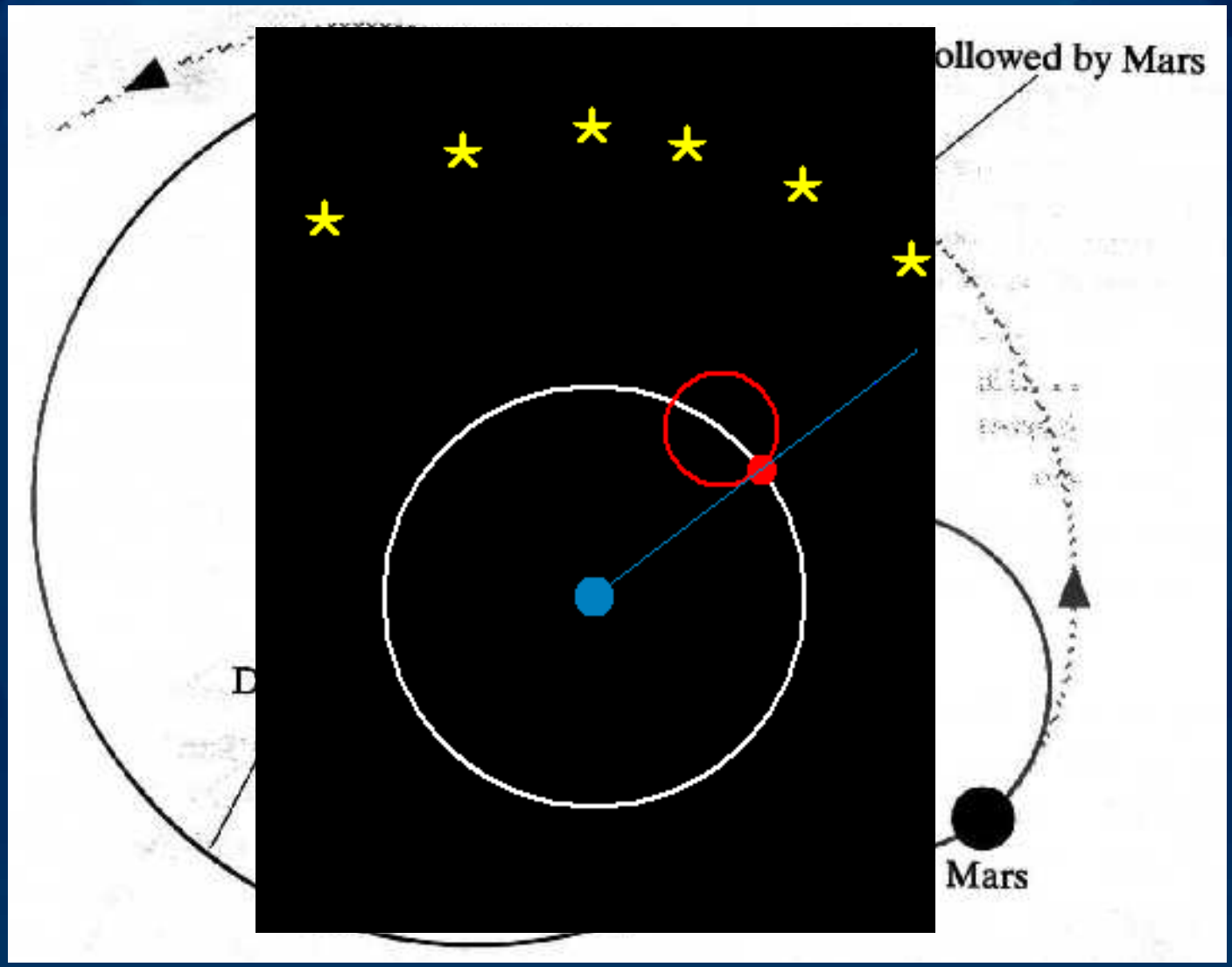
Synodic and Sidereal Periods

- Synodic period: time interval between successive conjunctions or oppositions, 1→ 3
- Sidereal period: time interval for one complete orbit relative to background stars, 1→2 (shown for Earth)



Epicycles on Deferents

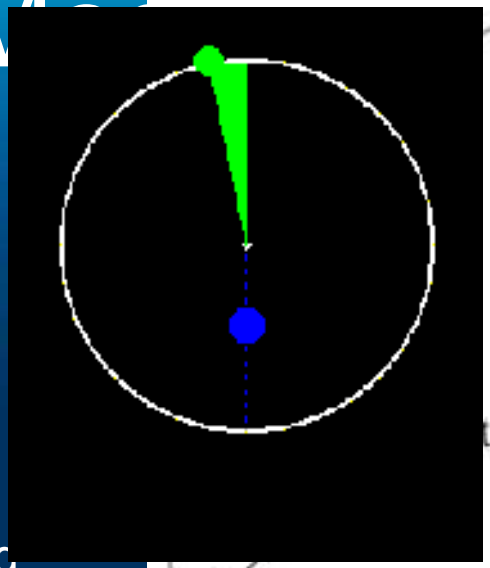
- Ptolemy et al. desired uniform circular motions

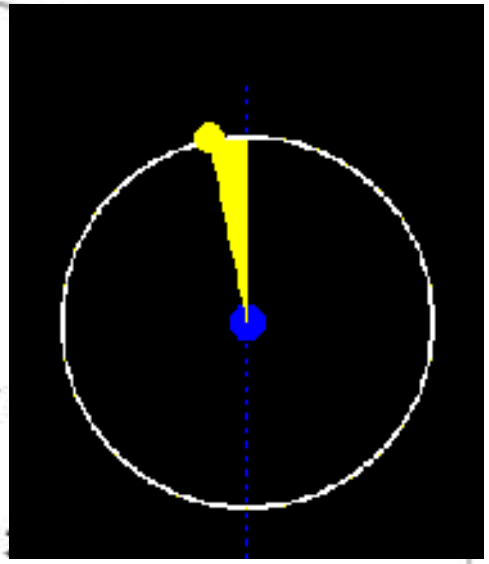


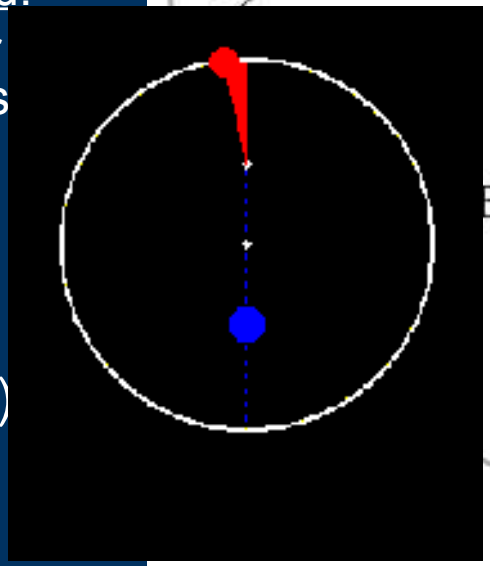
Ptolemy's M

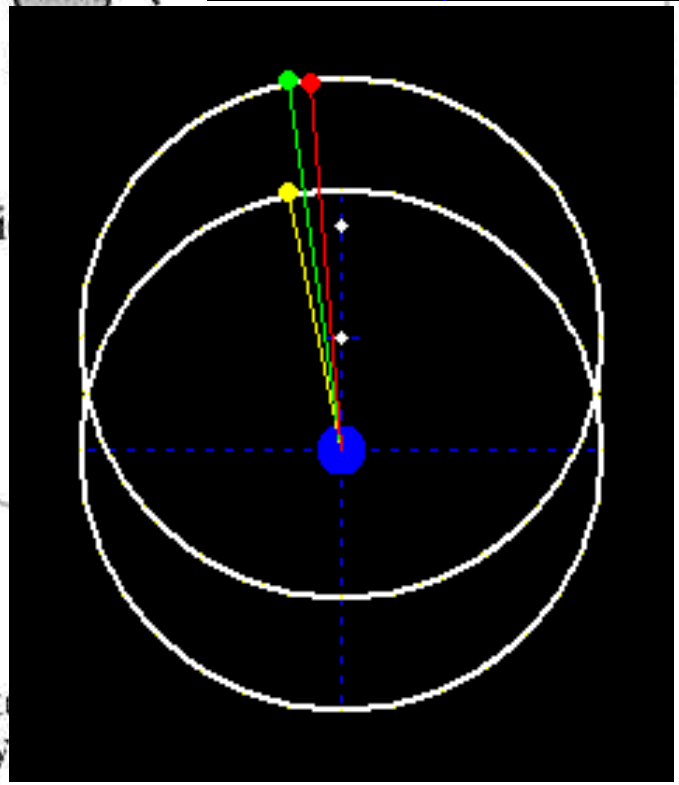
- Eccentric - displaces Earth from center
- Equant – center of epicycle has uniform angular speed when viewed from this point
- Period of planet around epicycle is synodic period.
- Period of epicycle center around deferent center is sidereal period.
- 80+ epicycles
- It works pretty well!

- Occam's Razor (1348)
  - Accept the simplest explanation





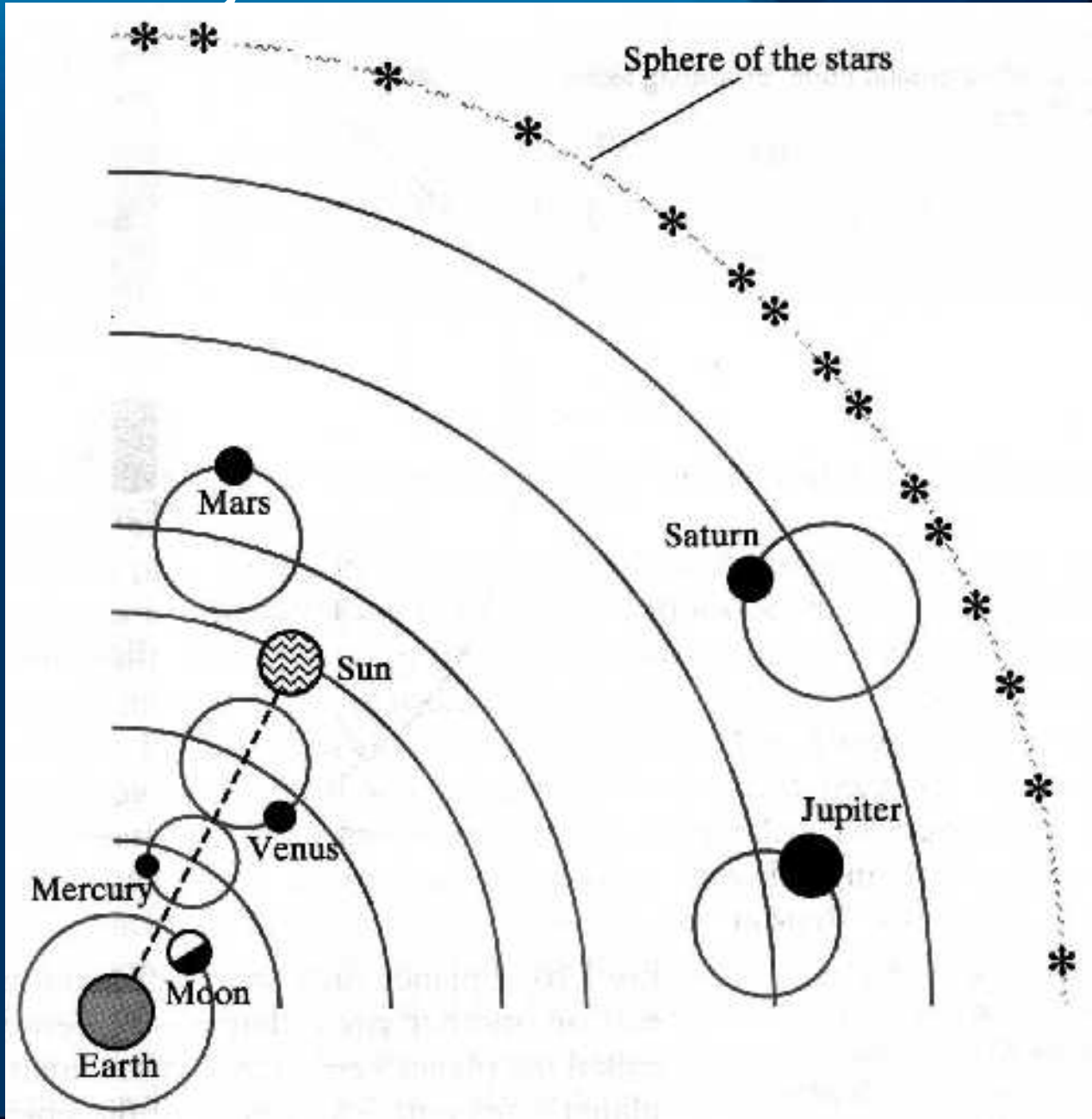




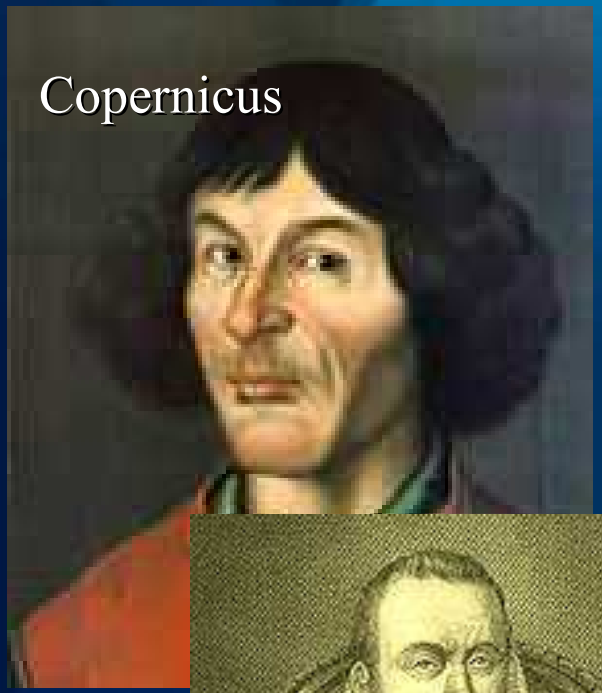
Ptolemy's Model

- Venus and Mercury on invisible "bar"
- Speed is still a problem

FIGURE 1.12
The ancient astronomer Ptolemy, A.D. 85–165. Using epicycles and many other theoretical devices, he prefected the Earth-centered theory of the layout of the universe.

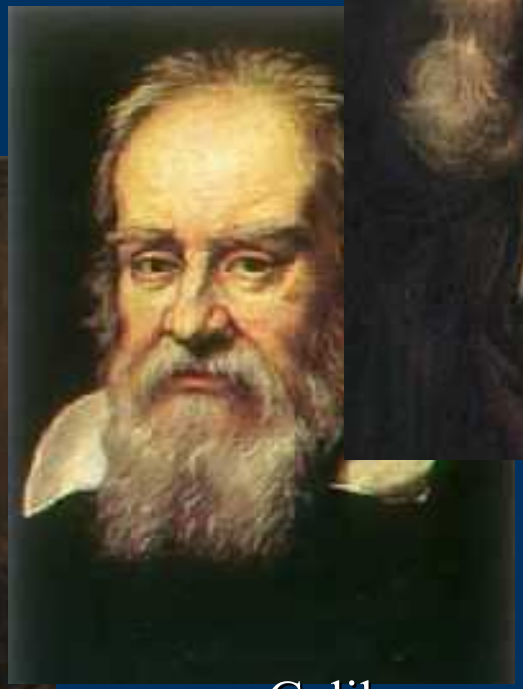


The Copernican Revolution
1543 - 1727


Copernicus

Tycho


Kepler


Galileo


Newton

A Summary of the Early History of Astronomy

Observations	Typical Dates	Theories
Stars, sun, moon, and planets are moving overhead.	3000 B.C.	
	500	Pythagorean theory: Earth-centered transparent spheres.
Each planet moves at a varying rate; retrograde motion.	400	Theory of multiple Earth-centered transparent spheres.
	300	Aristarchus's theory: sun-centered circles.
Heaven and Earth seem different; Earth seems motionless, apparently contradicting Aristarchus's theory.	200	
Planets are brighter during retrograde motion.	100	Theory of Earth-centered epicycles.
Detailed quantitative measurements show need for small corrections.	0	Ptolemy's theory: Earth-centered epicycles, equants.
	A.D. 100	
	1500	Copernicus's theory: sun-centered circles.
Brahe's accurate measurements disprove Ptolemy's and Copernicus's theories.	1600	Kepler's theory: sun-focused ellipses.
Galileo's telescopic observations disprove Earth-centered theories.		