History of Astronomy

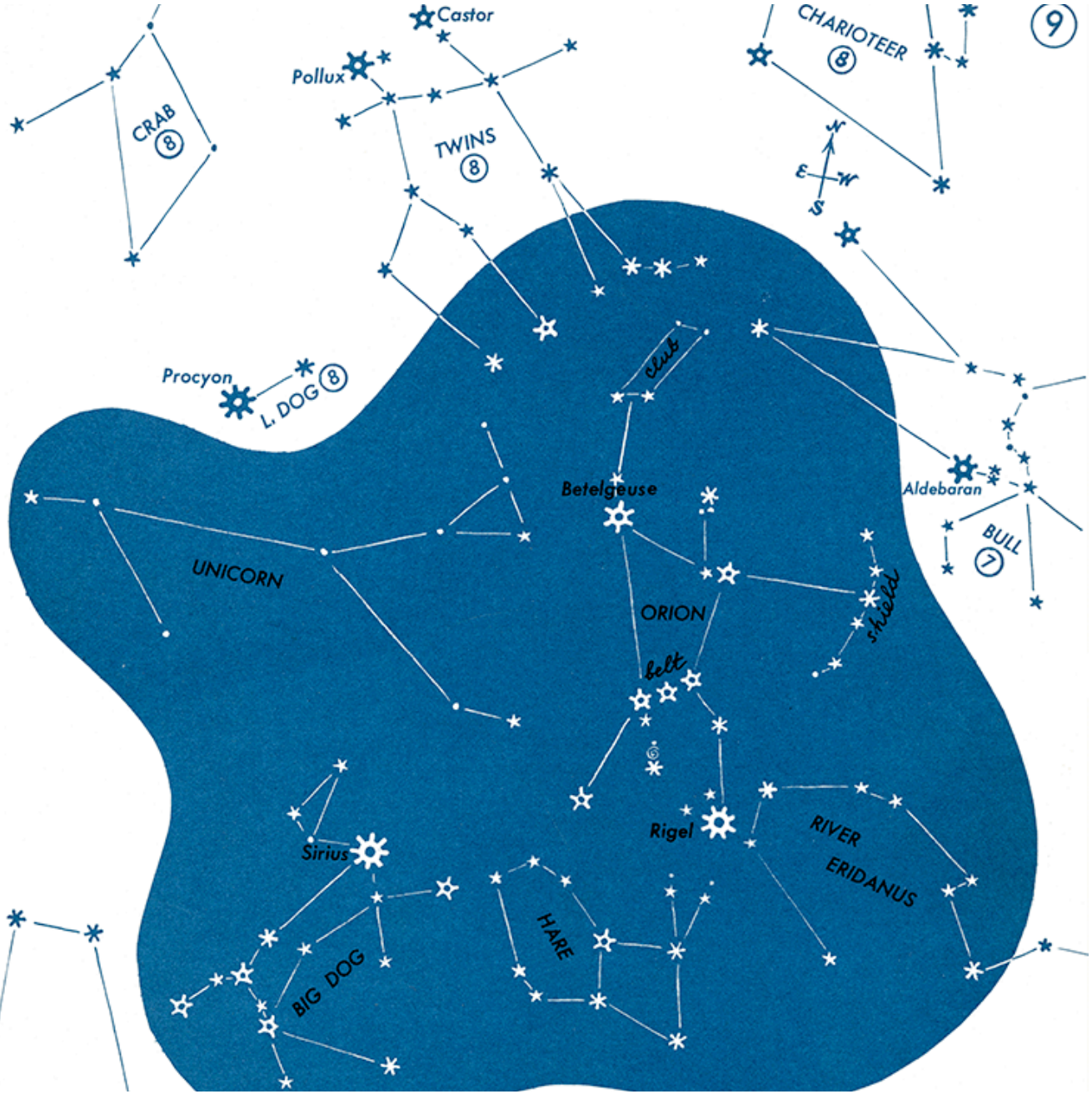
Ancient Astronomy

What did ancient civilizations use astronomy for?

- daily timekeeping
- tracking the seasons and calendar
- monitoring lunar cycles
- monitoring planets and stars
- predicting eclipses
- and more…

The sky was a map, a clock , a calendar, and a book of stories

Constellations



From H.A. Rey's book
The Stars

Not All Constellations are “Connect the Dots”…

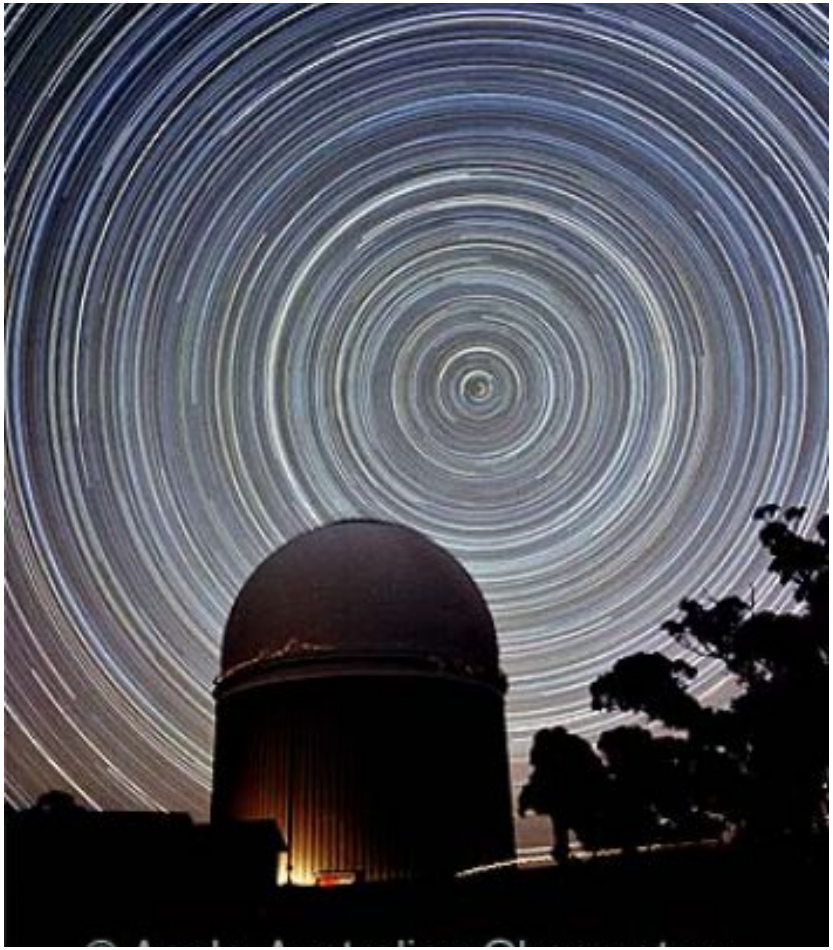
Australian Aboriginal astronomers made figures out of the dark clouds in the Milky Way – “The emu in the sky”.

What We See When We Look Up

Motions in the Sky

The Circling Sky

the rotation of the Earth about its axis *day*



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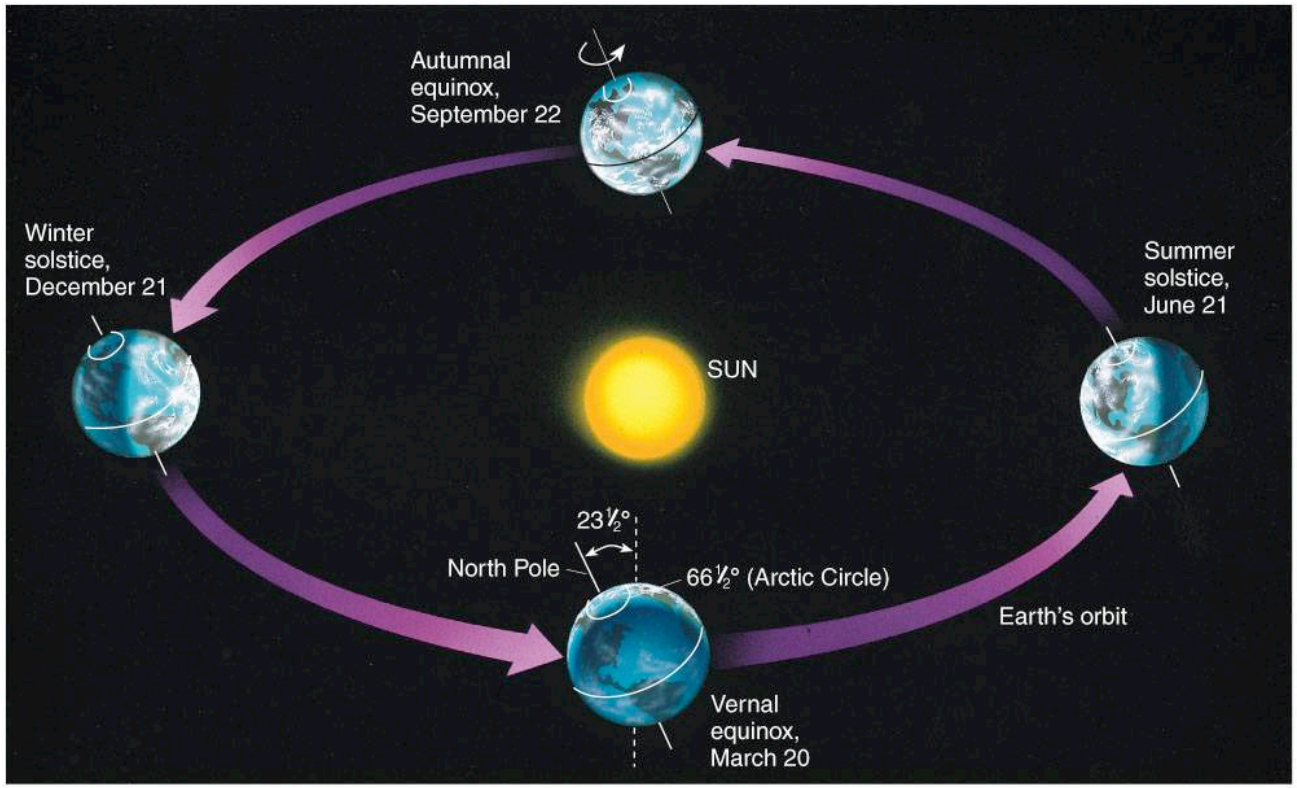
The Reason for Seasons

the Earth's orbit around the Sun *year*



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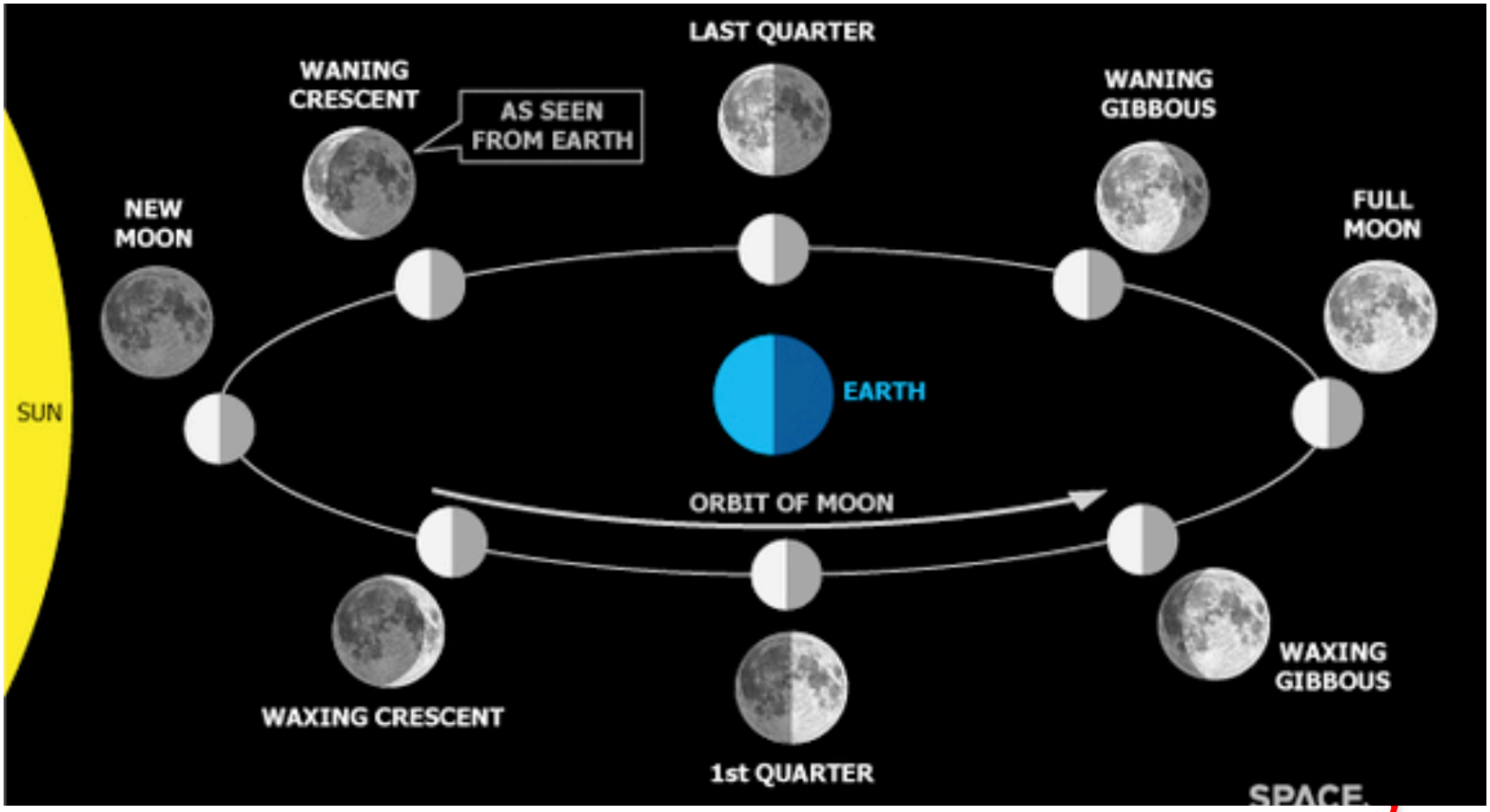

The Moon, Our Constant Companion *month*

the Moon's orbit around the Earth

What We See When We Look Up

Motions in the Sky

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the rotation of the Earth about its axis — *day*

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The Moon, Our Constant Companion

the Moon's orbit around the Earth — *month*

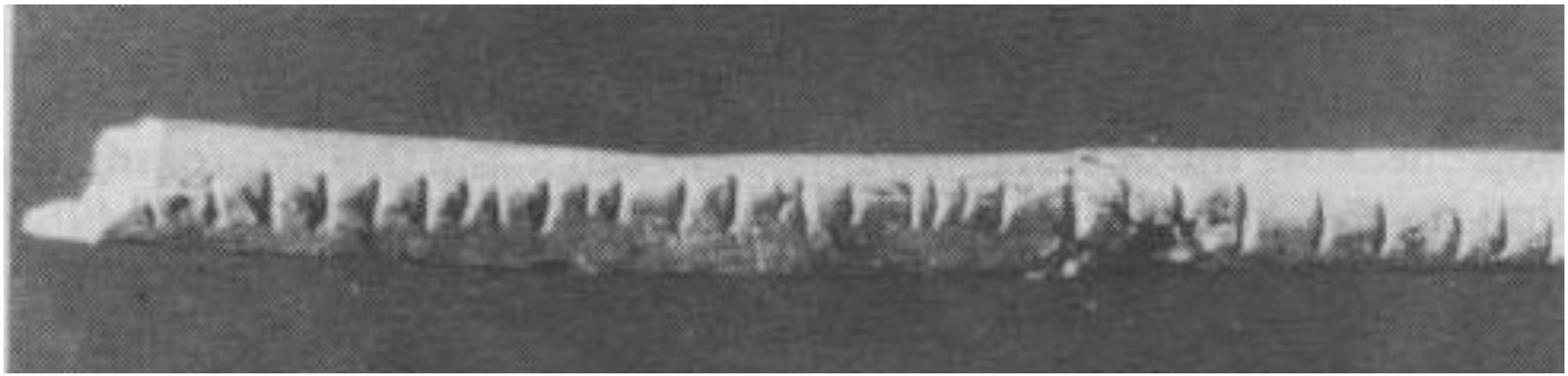
The Ancient Mystery of the Planets

the various planets' orbits around the Sun — *week*

Days of week were named for Sun, Moon, and *visible* planets

Object	*Teutonic Name*	*English*	*French*	*Spanish*
Sun	Sun	Sunday	dimanche	domingo
Moon	Moon	Monday	lundi	lunes
Mars	Tiw	Tuesday	mardi	martes
Mercury	Woden	Wednesday	mercredi	miércoles
Jupiter	Thor	Thursday	jeudi	jueves
Venus	Fria	Friday	vendredi	viernes
Saturn	Saturn	Saturday	samedi	sábado

Swaziland: Lemombo bone from ~35,000 B.C. may suggest recording of lunar cycle (29 marks)



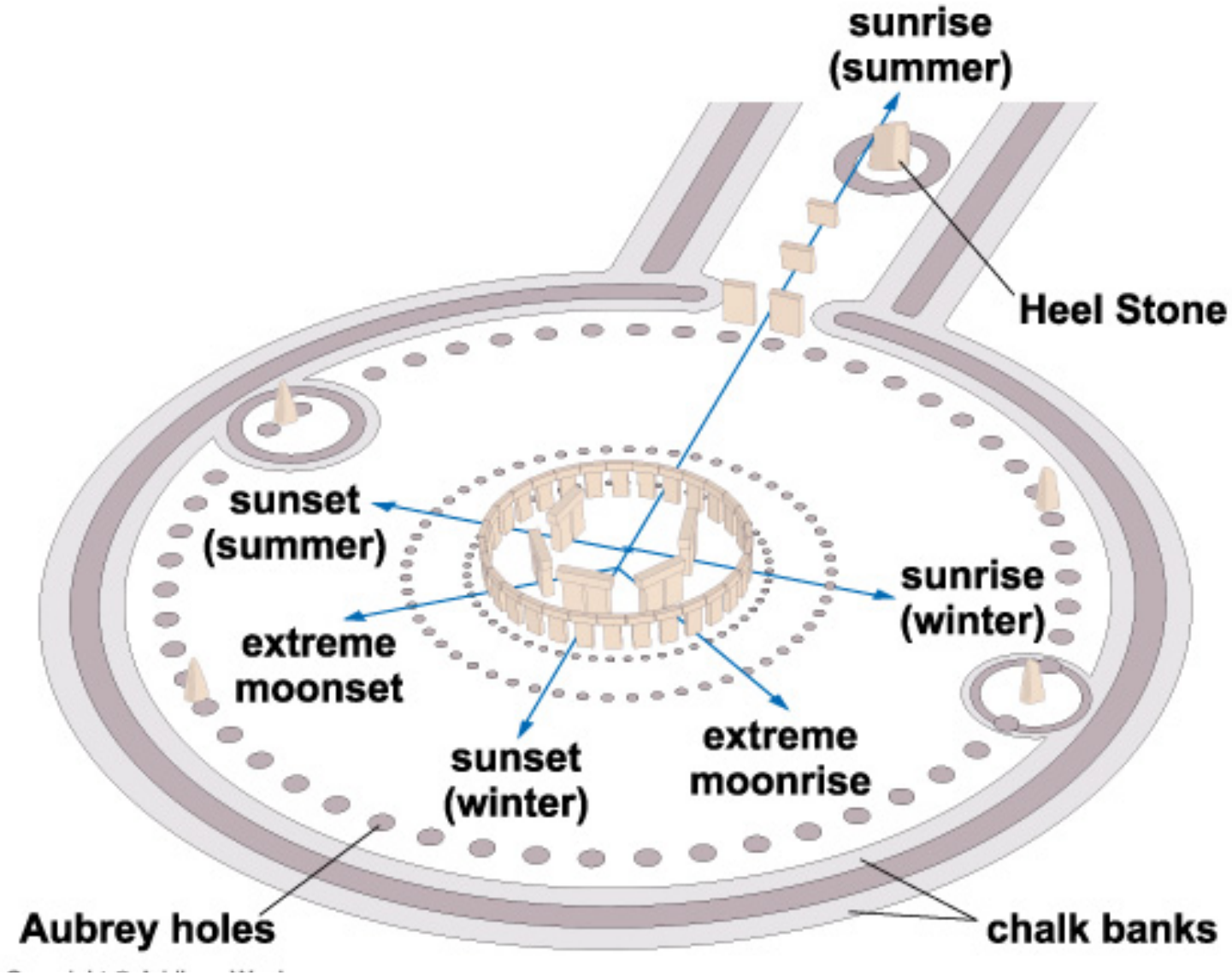
France: Cave paintings from 18,000 B.C. may suggest knowledge of lunar phases (29 dots)

- Assyrian Cuneiform Tablets ~3000 B.C.

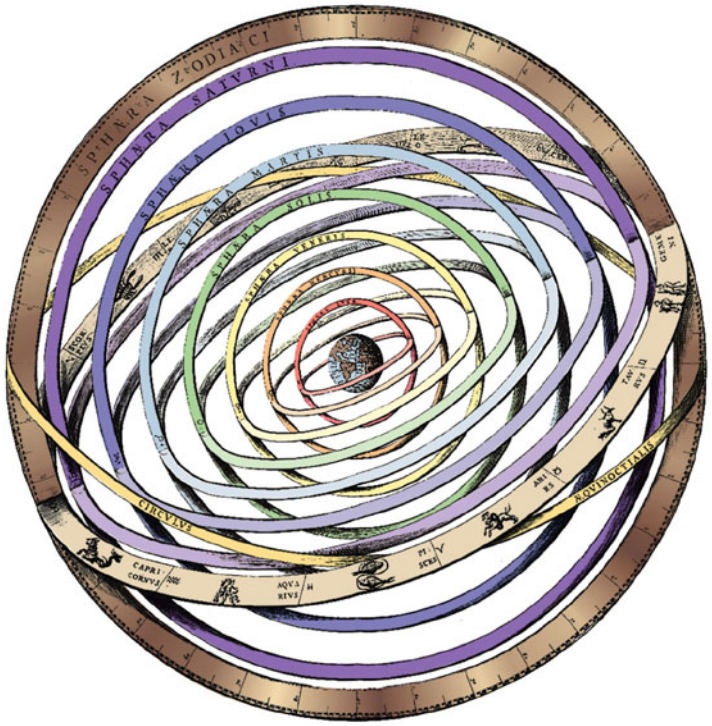
Example translation from R.C. Thompson's book *The Reports of the Magicians and Astrologers of Nineveh and Babylon (1900)*:

"When Venus fixes its position, the days of the king will be long, there will be justice in the land."

England: Stonehenge (completed around 1550 B.C.)



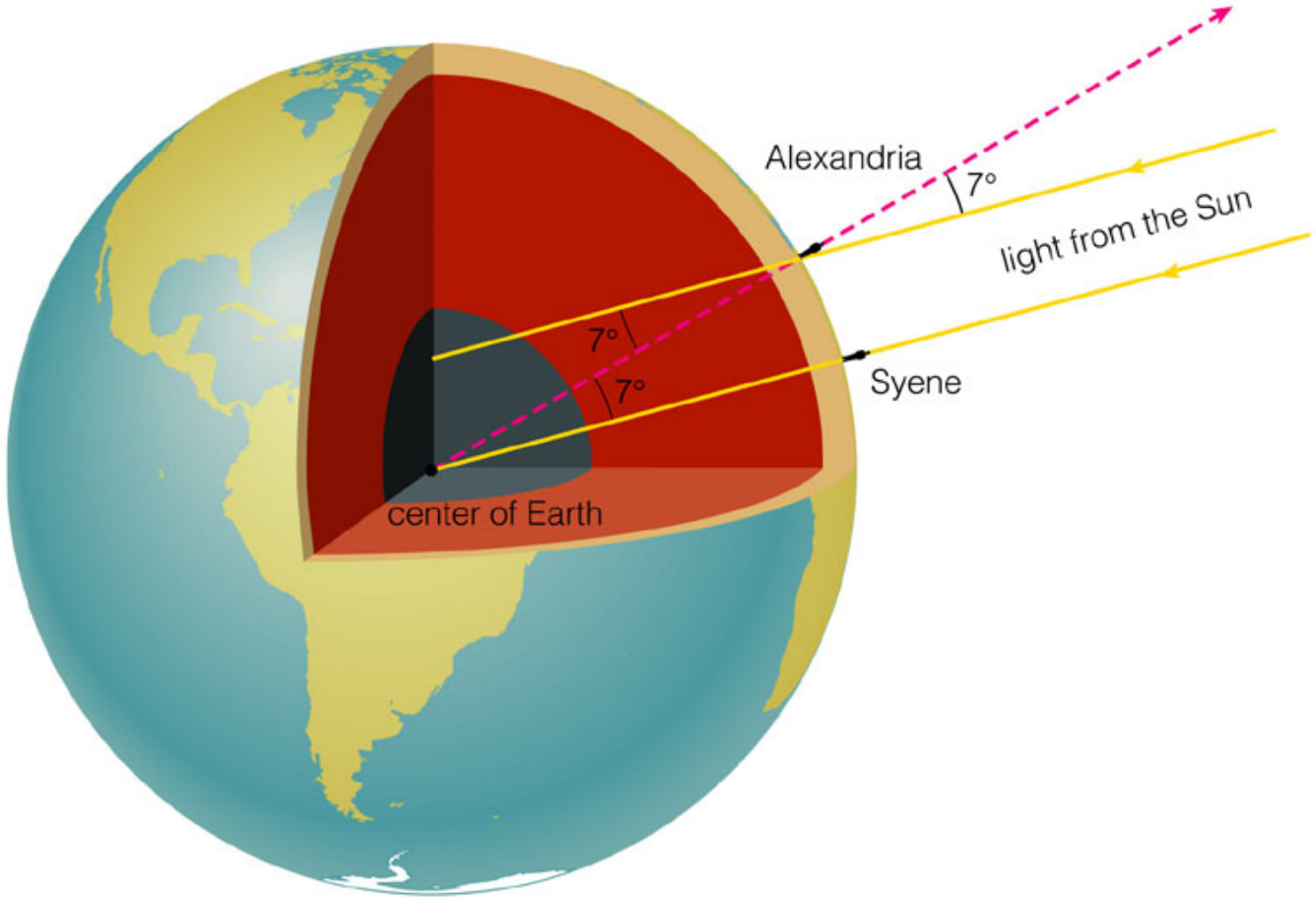
Why does modern science trace its roots to the ancient Greeks?



Greek geocentric model (c. 400 B.C.)

- Greeks were the first people known to make ***models*** of nature.
- They tried to explain patterns in nature without resorting to myth or the supernatural.
- They applied math and logic to explanations of natural phenomena

Eratosthenes measures Circumference of the Earth (c. 240 BC)



Eratosthenes measured a value of ≈ 42,000 km (modern value 40,075 km)

Greek Science

Differing views on life in the universe:

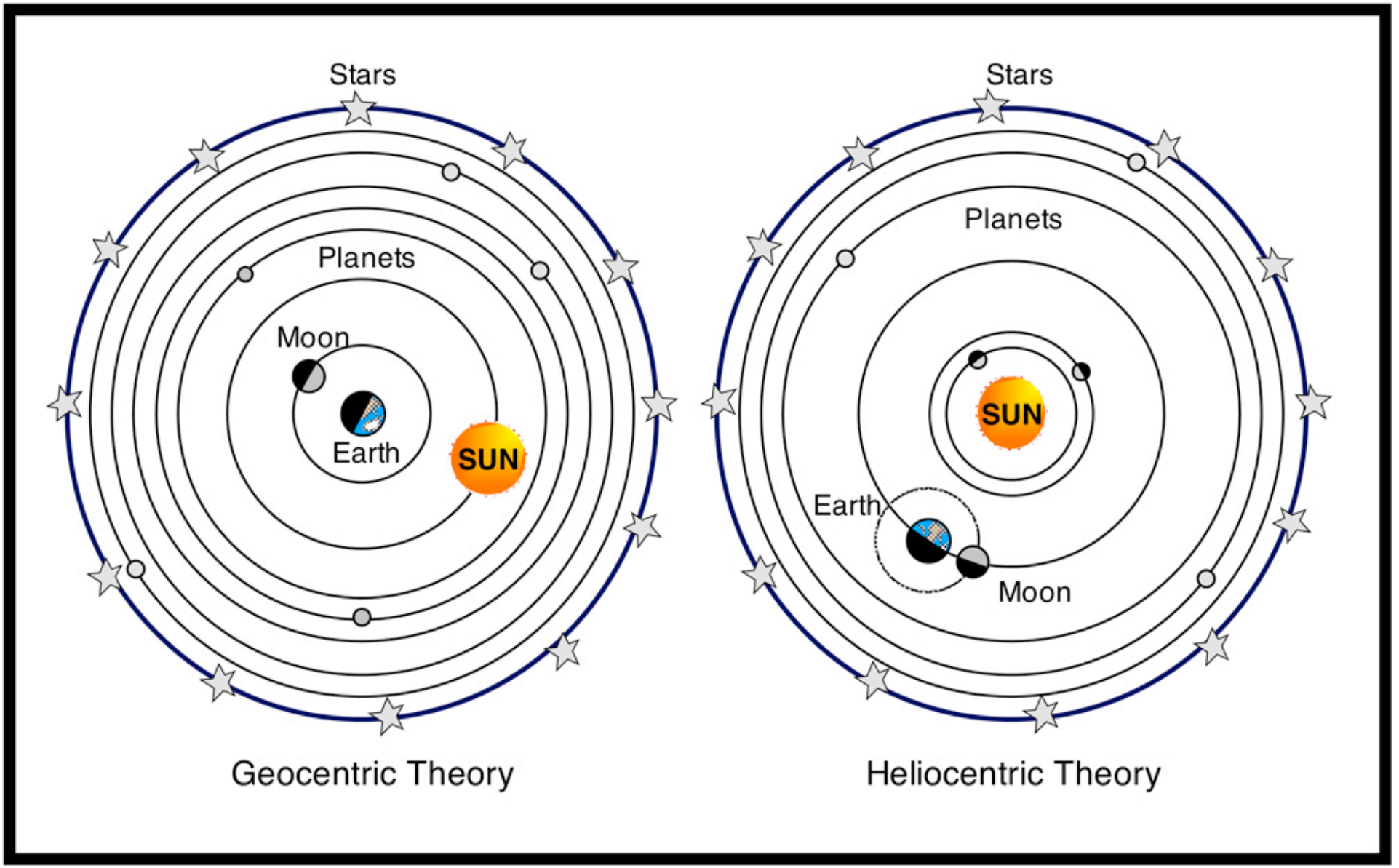
"There are infinite worlds both like and unlike this world of ours… we must believe that in all worlds there are living creatures and plants and other things we see in this world."

Epicurus (341-270 B.C.) "Letter to Herodotus"

"The world must be unique… There cannot be several worlds."

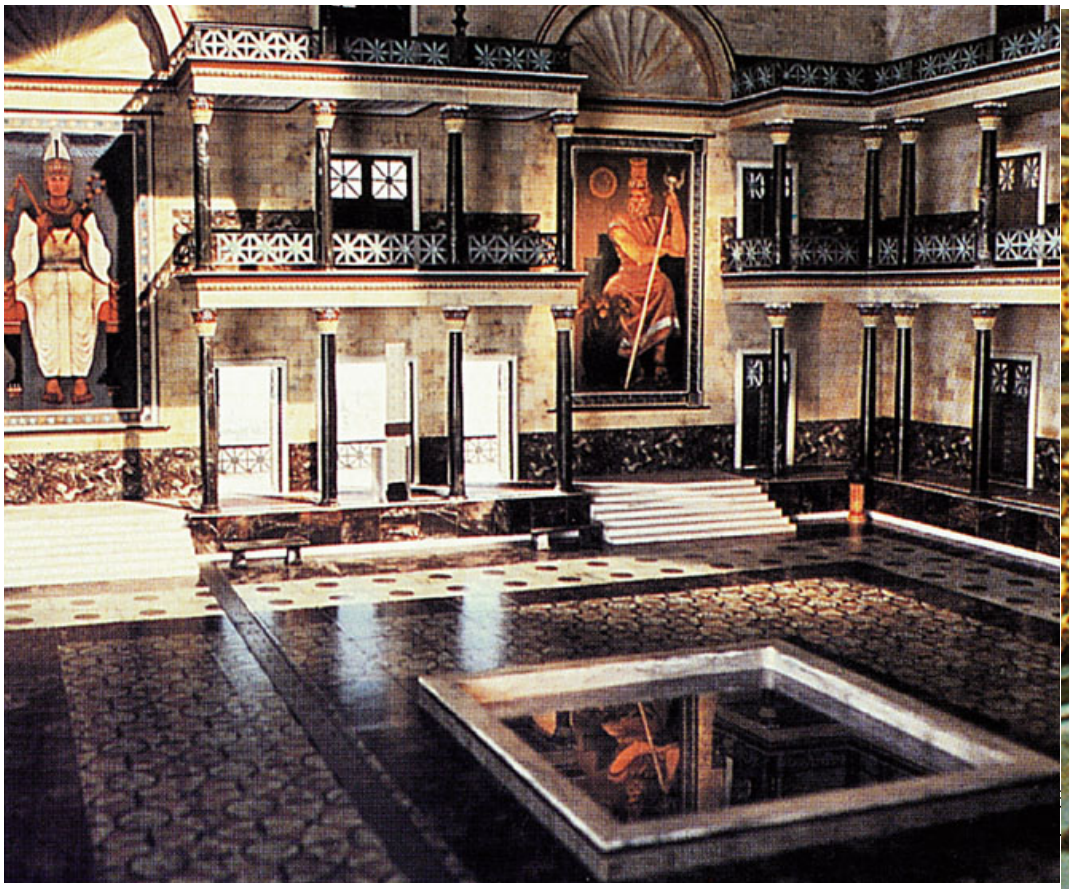
Aristotle (384-322 B.C.) "de Caelo"

Geocentric vs. Heliocentric Model



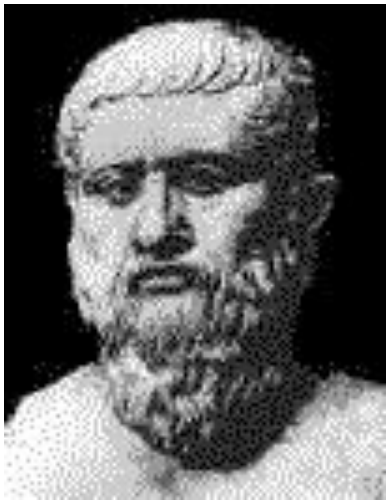
Artist's reconstruction of Library of Alexandria

Started by Alexander the Great. Collected over 1/2 million works during 700 years. Burned by anti-intellectual mob in 415 AD. Among texts losts are thought to be Aristarchus' Heliocentric model.



How did the Greeks explain planetary motion?

Underpinnings of the Greek geocentric model:

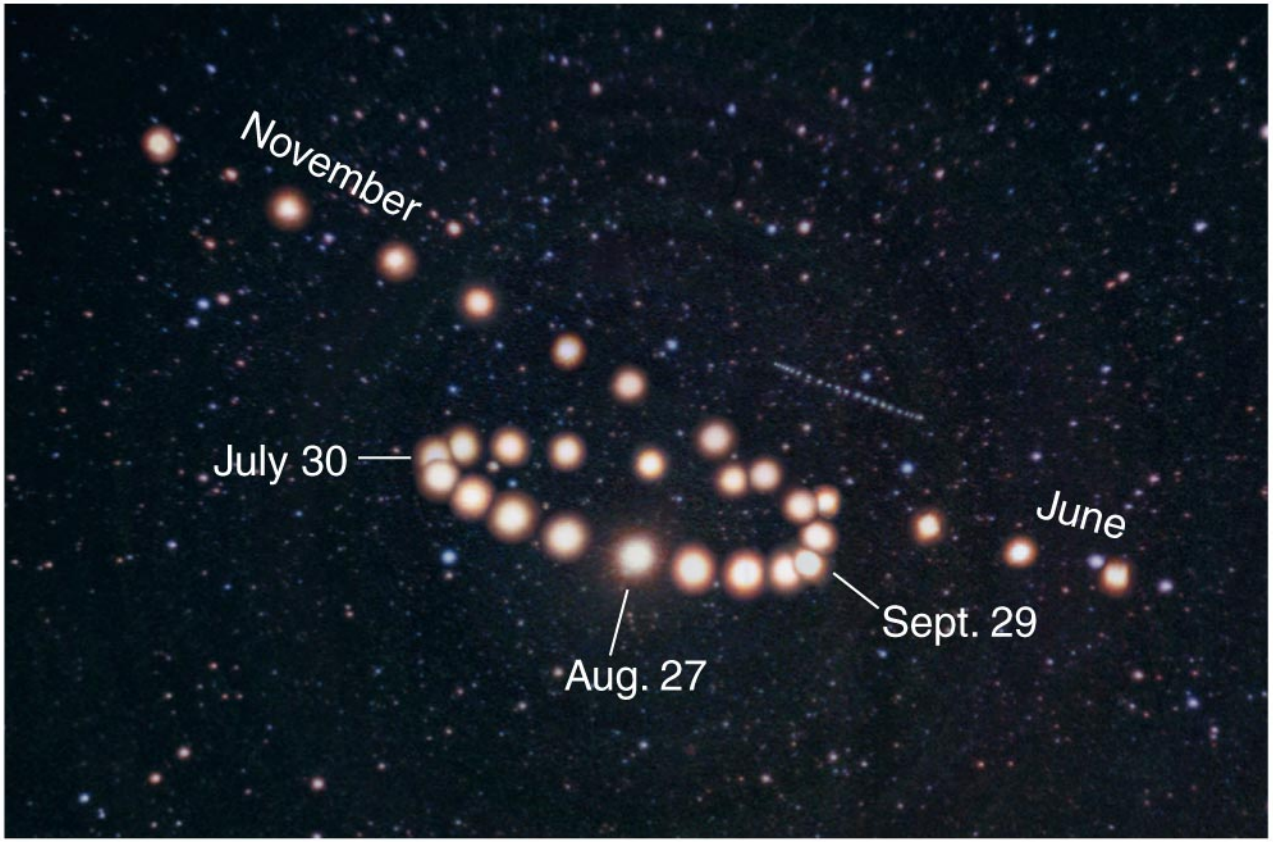


Plato

- Earth at the center of the universe
- Heavens must be "perfect" : objects moving on perfect spheres or along perfect circles (cf. Pythagoras)

Aristotle

But this made it difficult to explain apparent retrograde motion of planets…



Example: Over a period of 10 weeks, Mars appears to stop, back up, then go forward again relative to the fixed stars.

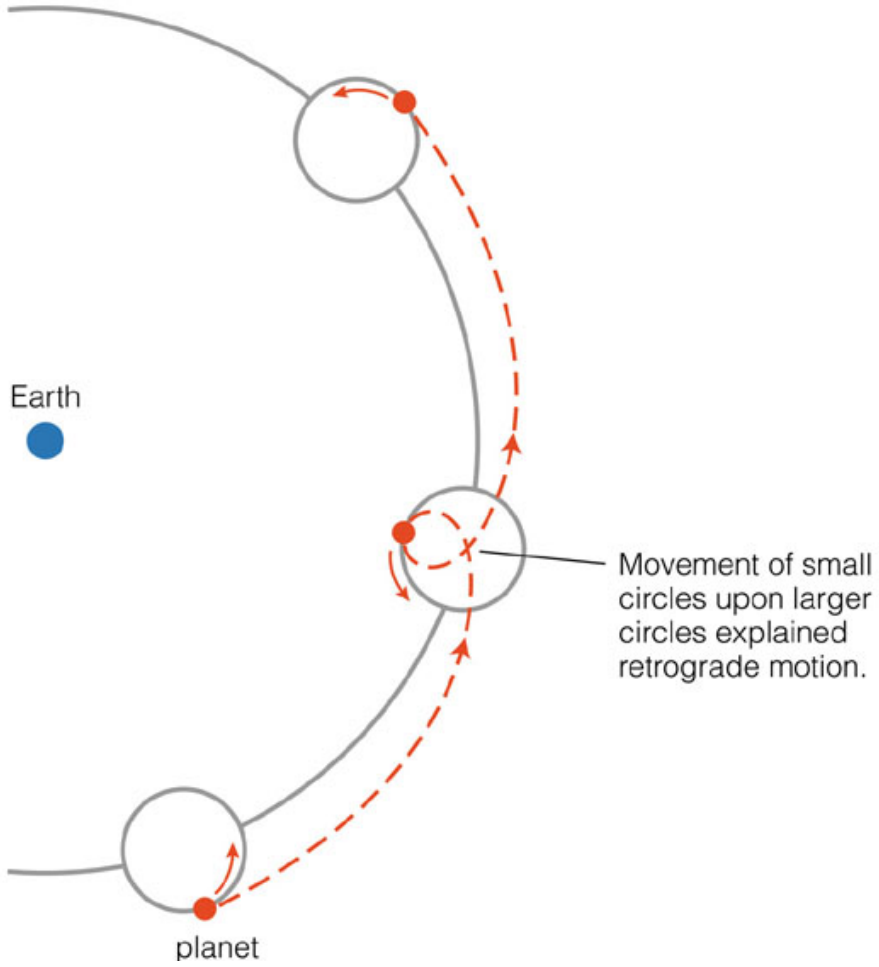
Ptolemy

The most sophisticated geocentric model was that of Ptolemy (A.D. 100-170) — called the **Ptolemaic model:**

• Sufficiently accurate to remain in use for 1,500 years. But needed up to 47 offset spheres to explain motions of only 7 celestial objects!

• Arabic translation of Ptolemy's work named *Almagest* ("the greatest compilation")

So how does the Ptolemaic model explain retrograde motion?
Planets *really do* go backward in this model..



The Copernican Revolution

Copernicus (1473-1543):

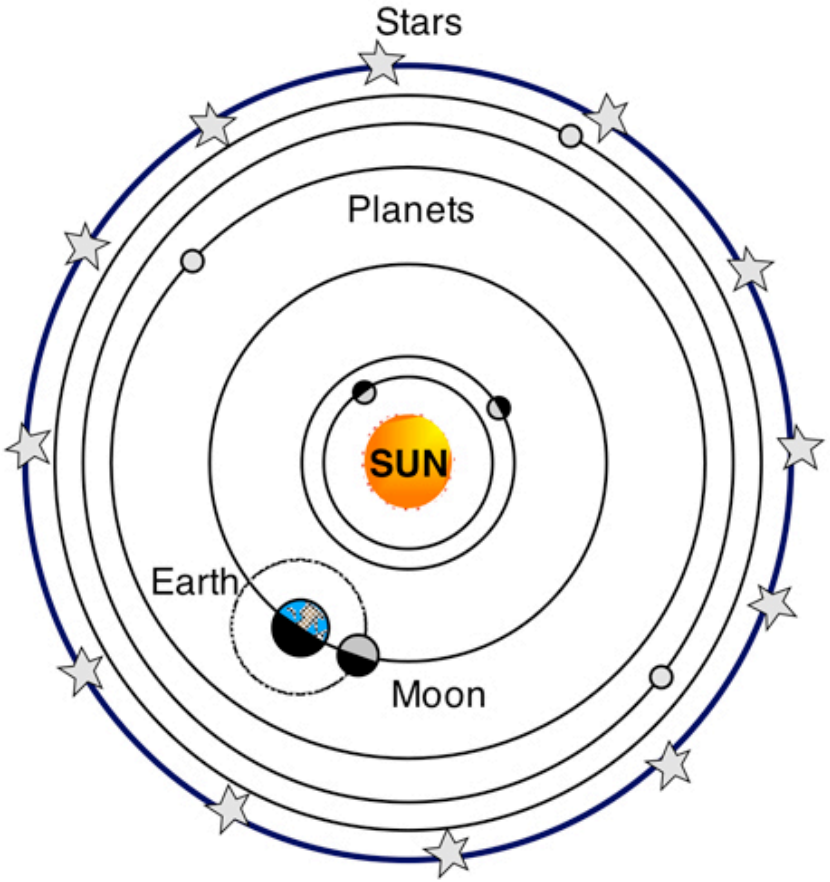
- Proposed the Sun-centered model (published on his death in 1543)
- Used model to determine layout of solar system (planetary distances in Earth-Sun units, or A.U.)

But . . .

- The model was no more accurate than Ptolemaic model in predicting planetary positions, because it still used perfect circles.

Copernicus' Heliocentric Model

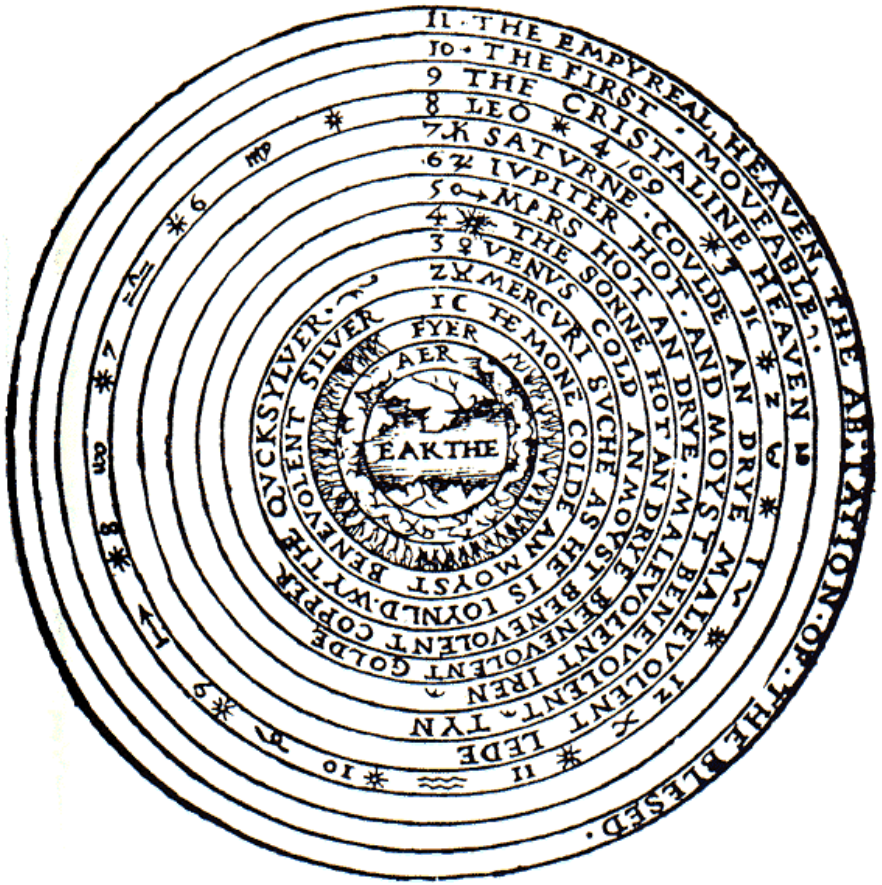
- Sun is at the center
- Earth orbits like any other planet
- Inferior planet orbits are smaller
- Retrograde motion occurs when we "lap" Mars and all the other superior or outer planets



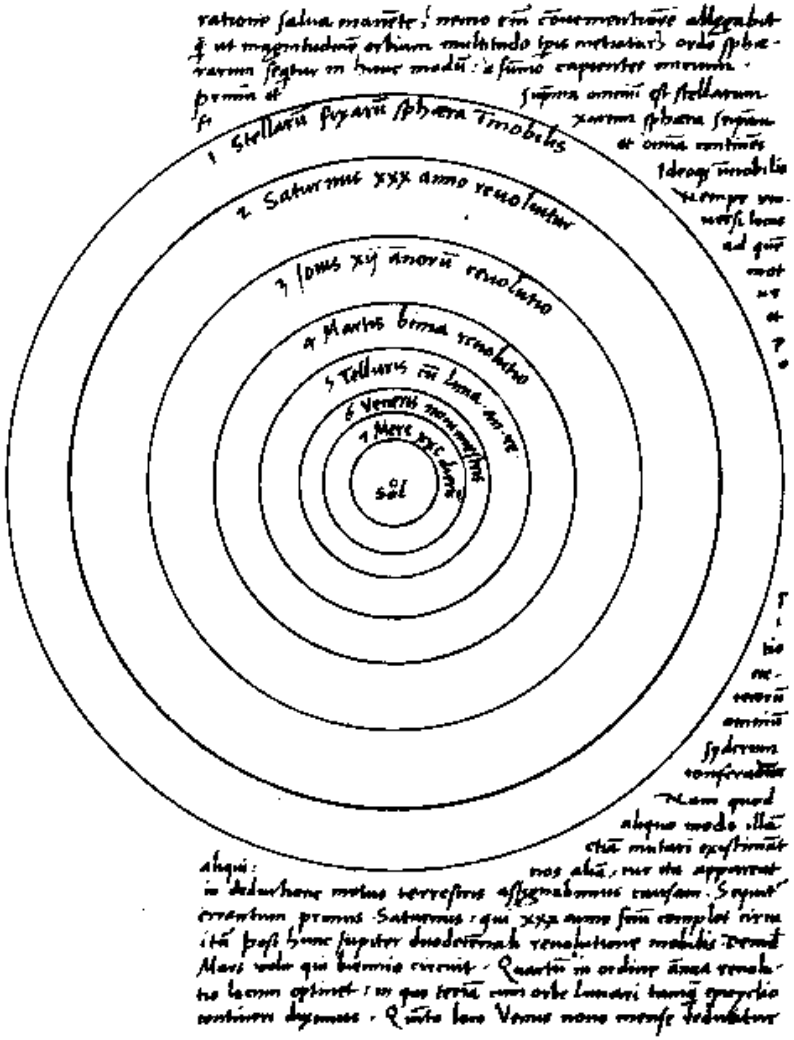
Heliocentric Theory

But, the stars must be very far away to see no

Why was replacing this…

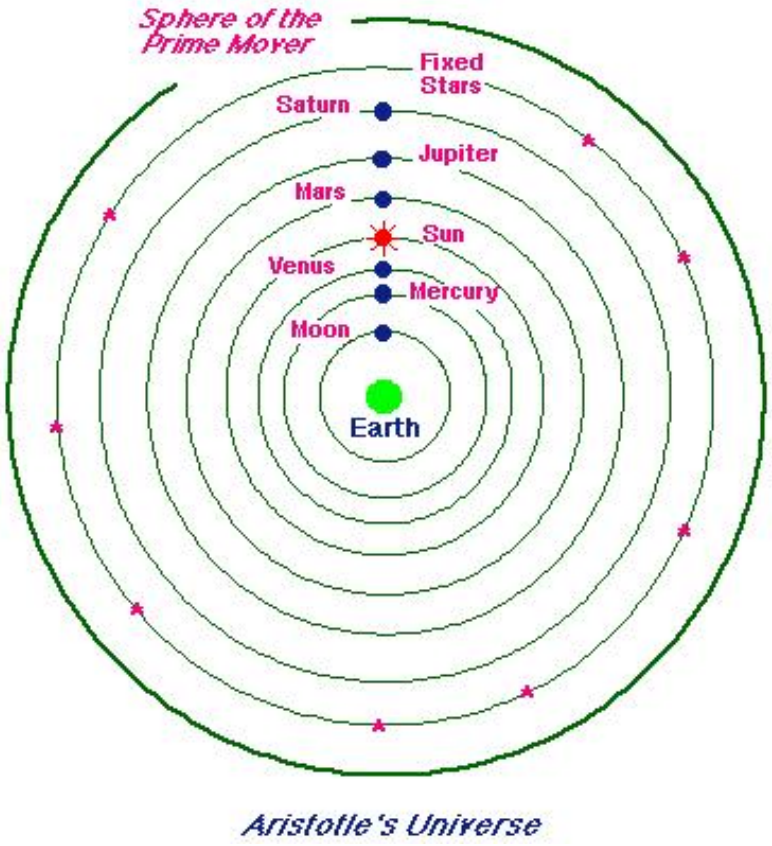


...with this so revolutionary?

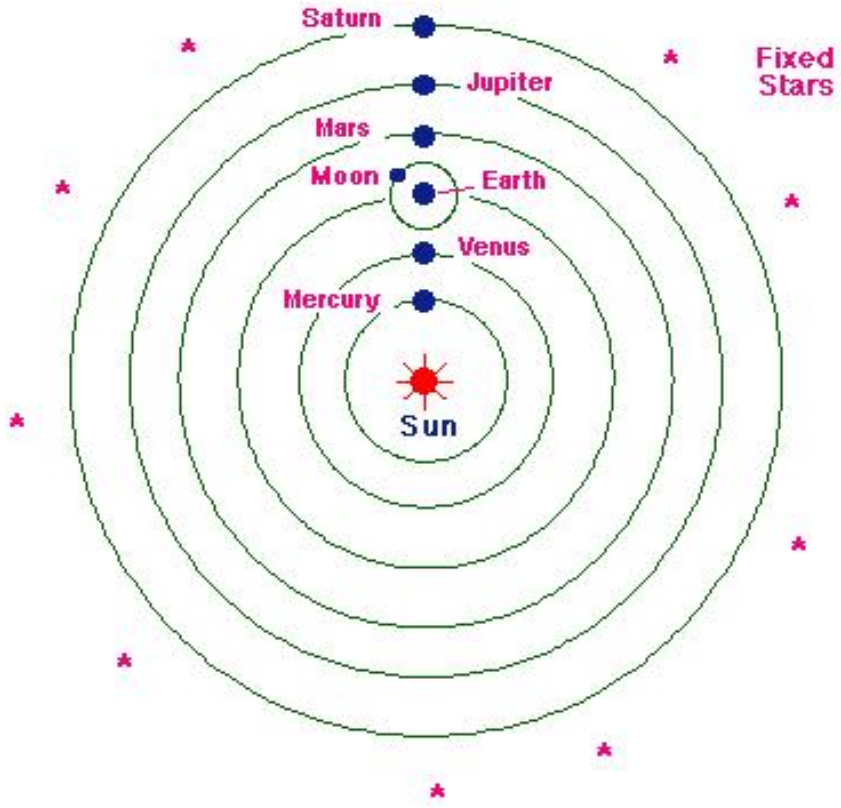


In part, because moving the Earth
from the center of creation challenged culture, religion, and our self-image.

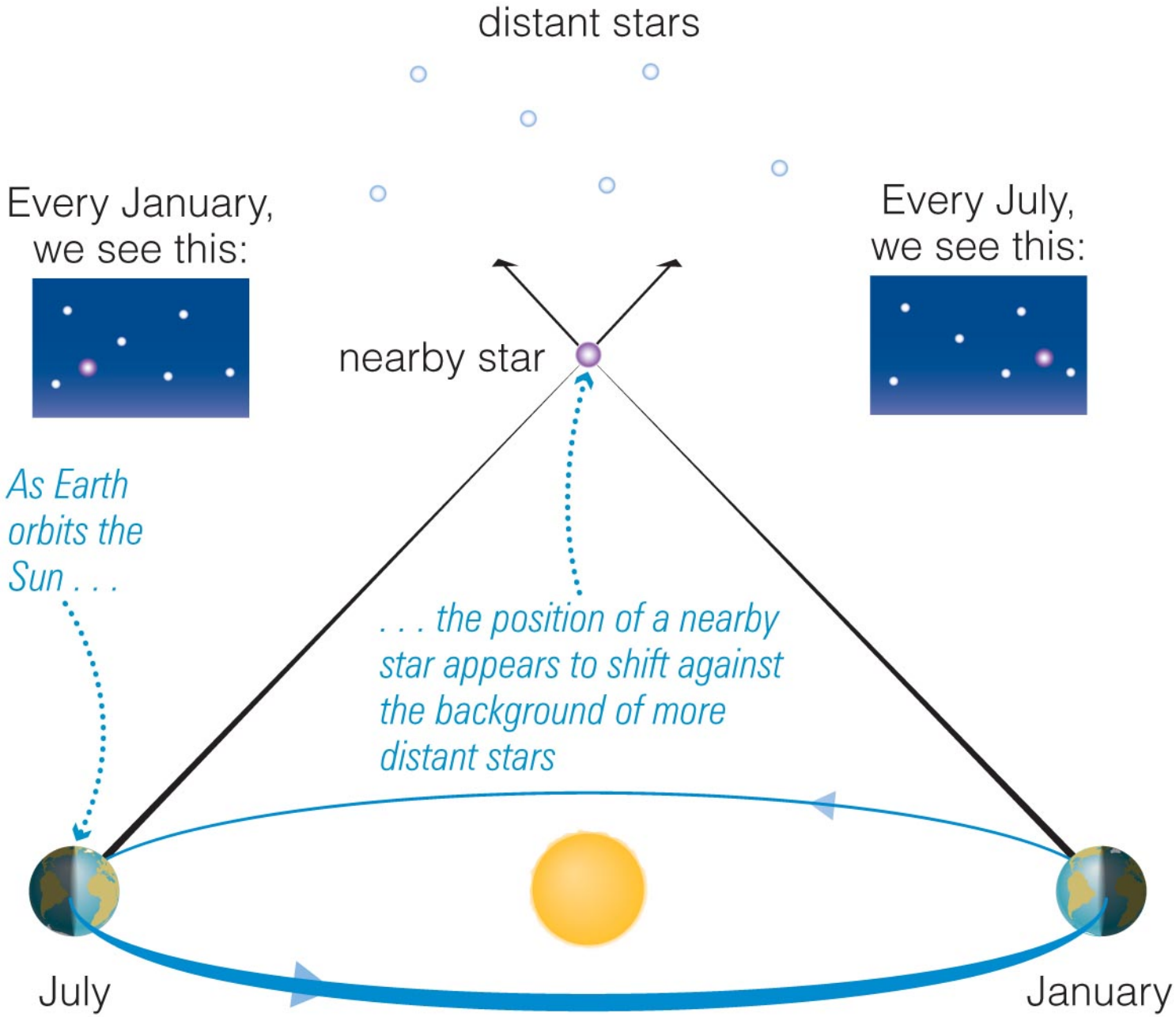
Why was the appearance of stars (brightness and parallax) such a key distinction between the geocentric and heliocentric models?



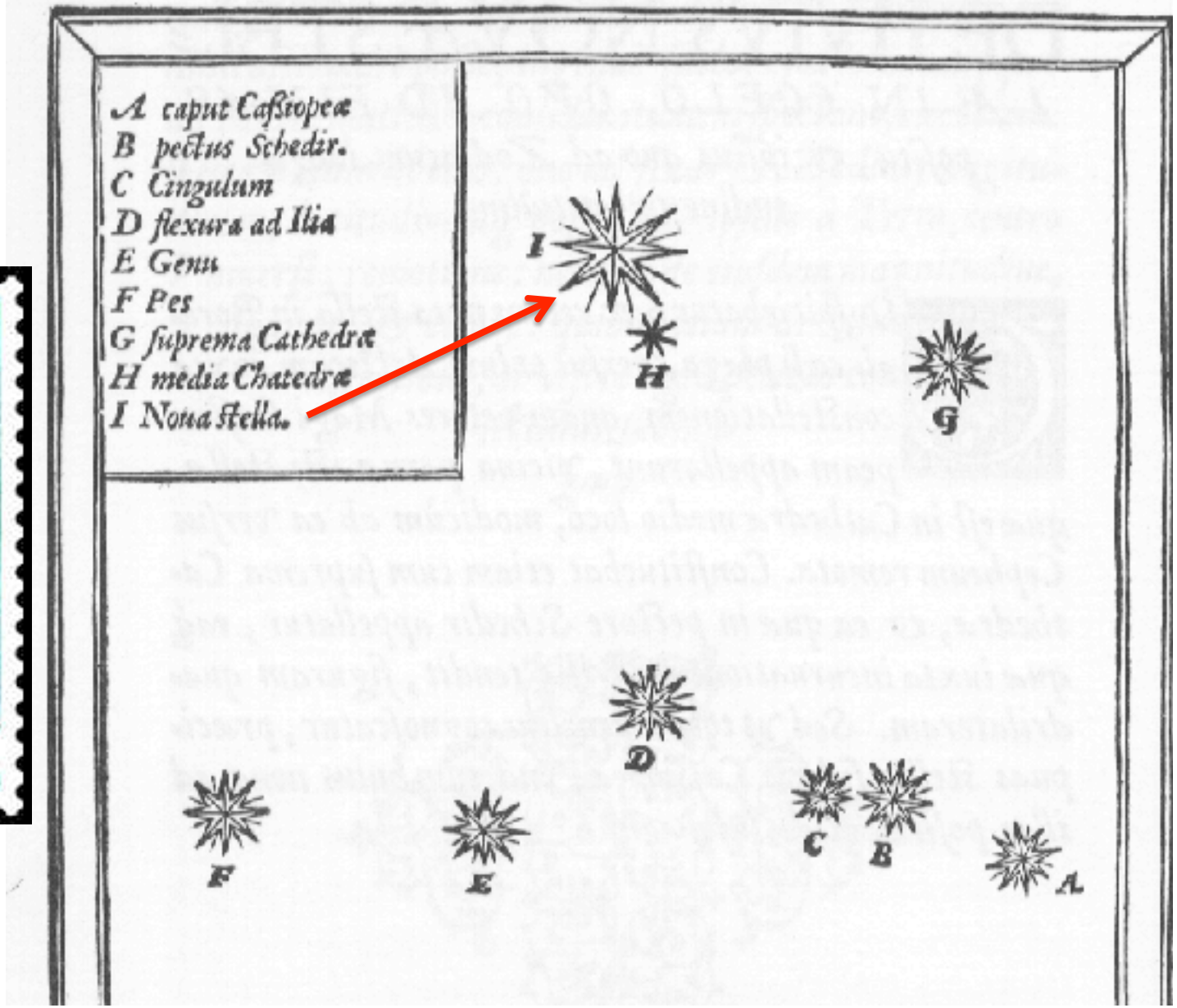
Aristotle's Universe



In the geocentric model the distance to all stars is constant, so they never change their brightness or relative positions (parallax), but in the heliocentric model this is only true if the stars are much further away than all the planets.


distant stars
Every January, we see this:
Every July, we see this:
nearby star
As Earth orbits the Sun . . .
. . . the position of a nearby star appears to shift against the background of more distant stars
July
January

Tycho Brahe (1572) Observes a New Star (Really a Supernova) … this event leads to his careful mapping of the heavens.



Tycho Brahe (1546-1601)

- Compiled the most accurate (one arcminute) naked eye measurements ever made of planetary positions.

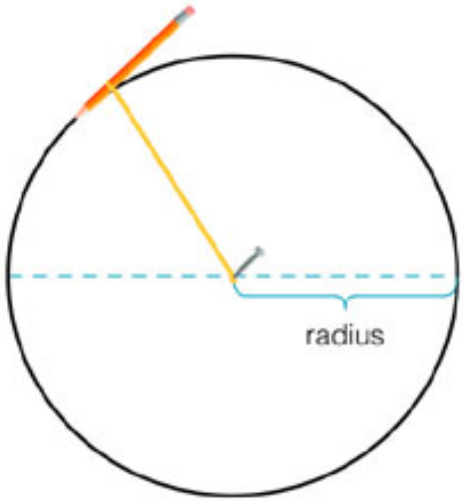
- Hired Kepler, who used his cumulative observations to discover the truth about planetary motion (orbits are elliptical).

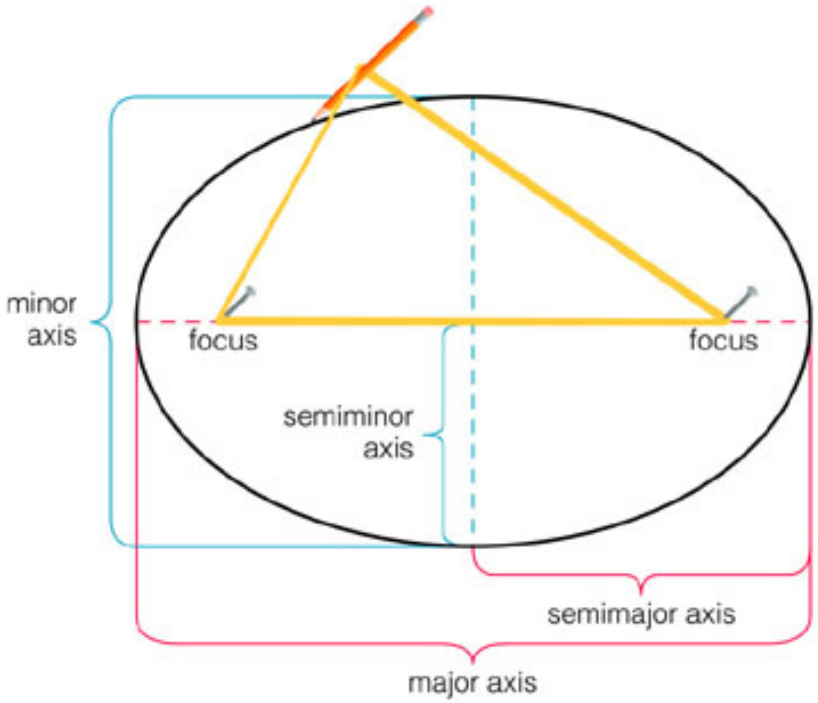
Johannes Kepler (1571-1630)

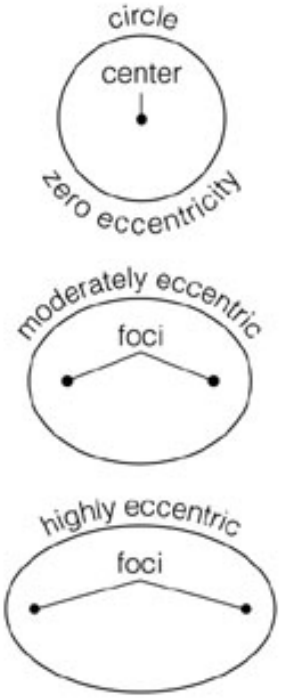
- Kepler first tried to match Tycho's observations with circular orbits
- But an 8 arcminute (1/4 of the Moon's apparent size on the sky) discrepancy led him eventually to ellipses…

"If I had believed that we could ignore these eight minutes [of arc], I would have patched up my hypothesis accordingly. But, since it was not permissible to ignore, those eight minutes pointed the road to a complete reformation in astronomy."

What is an Ellipse?

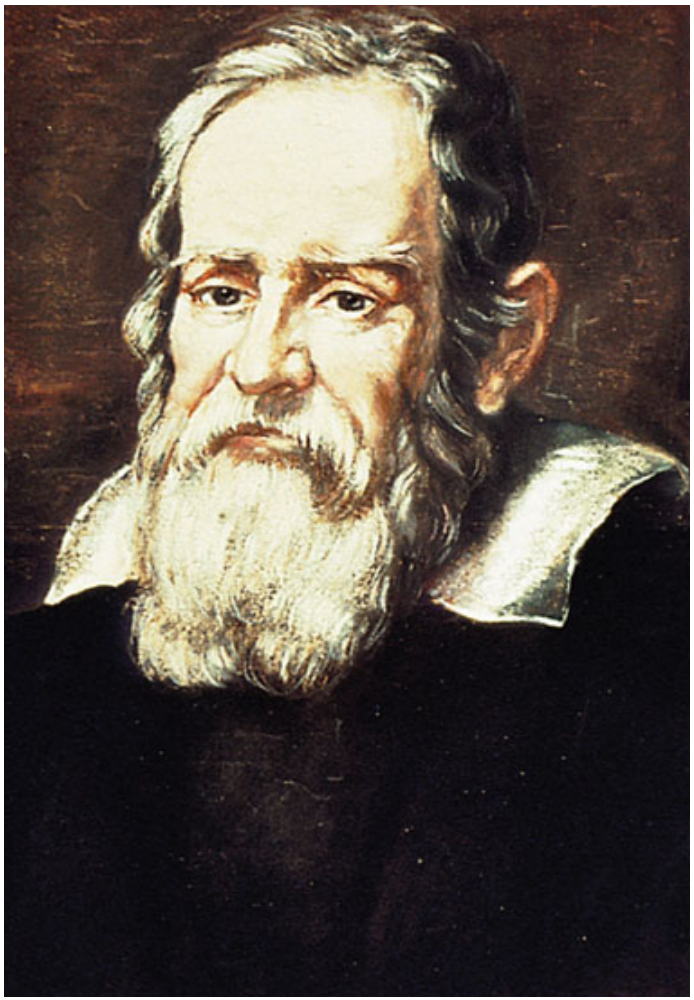






An ellipse looks like an elongated circle

How did Galileo solidify the Copernican revolution?



Galileo (1564-1642) overcame major objections to Copernican view. Three key objections rooted in Aristotelian view were:

1. **Earth could not be moving because objects in air would be left behind.**
2. **Non-circular orbits are not "perfect" as the heavens should be.**
3. **If Earth were really orbiting Sun, we'd detect stellar parallax.**

Overcoming the first objection (nature of motion):

Galileo's experiments showed that objects in air would stay with a moving Earth.

- Aristotle thought that all objects naturally come to rest.

- Galileo showed that objects will stay in motion unless a force acts to slow them down (Newton's first law of motion).

Overcoming the second objection (heavenly perfection):

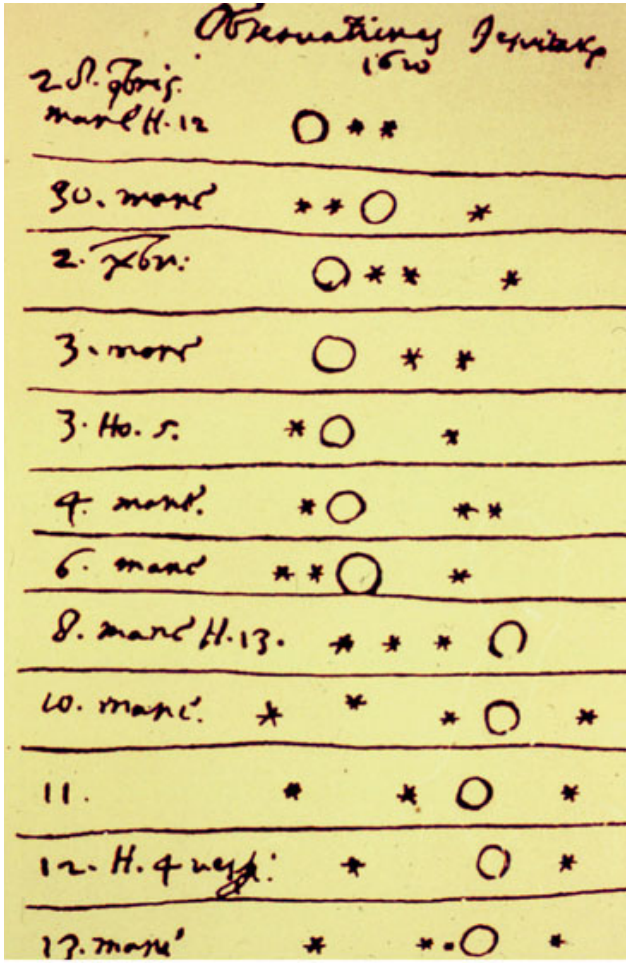
- Tycho's observations of comet and supernova already challenged this idea.
- Using his telescope, Galileo saw:
  - ✓ sunspots on Sun ("imperfections")
  - ✓ mountains and valleys on the Moon (proving it is not a perfect sphere)

Overcoming the third objection (parallax):

• Tycho *thought* he had measured stellar distances, so lack of parallax seemed to rule out an orbiting Earth.

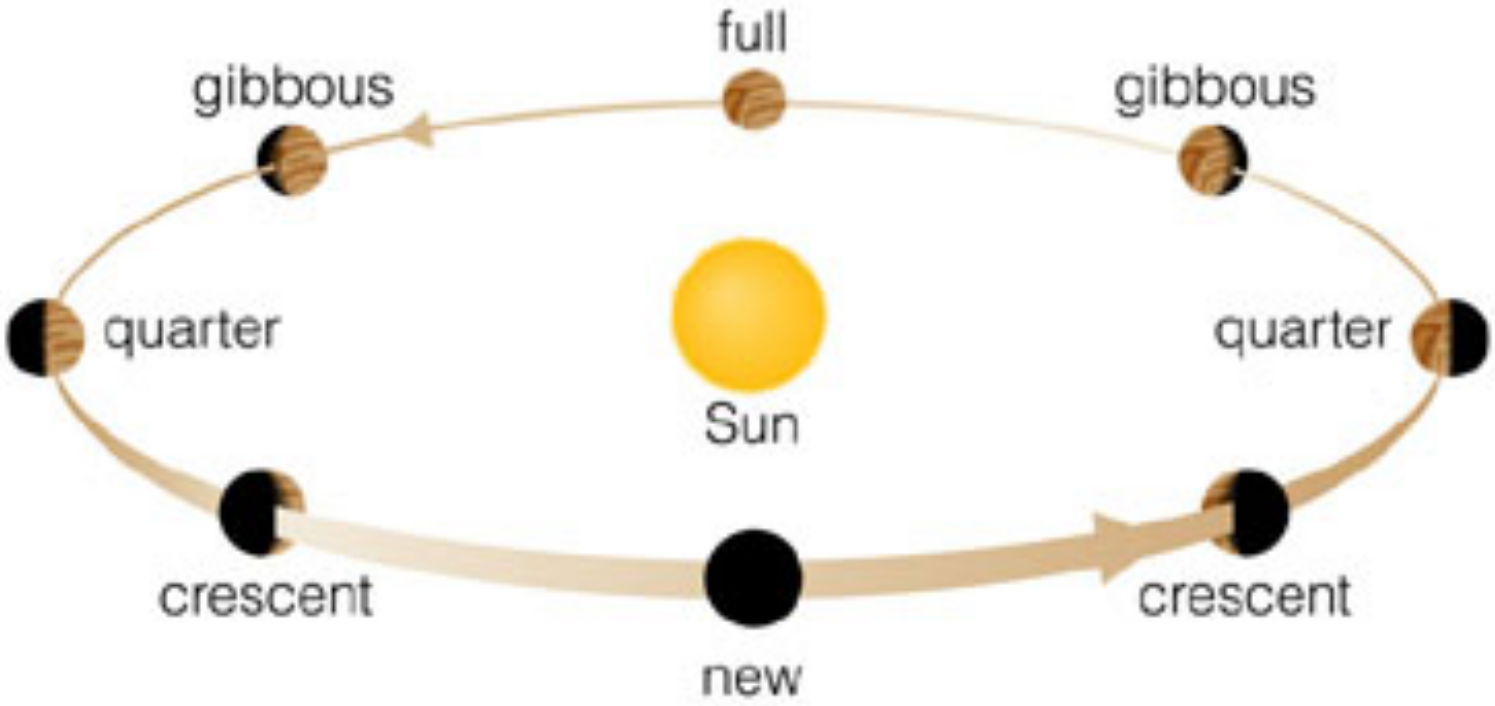
• Galileo showed stars must be much farther than Tycho thought — in part by using his telescope to see the Milky Way is made of countless individual stars.

✓ If stars were much farther away, then the lack of detectable parallax was no longer so troubling.



Galileo also saw four moons orbiting Jupiter, proving that not all objects orbit the Earth…

Venus Phases



…and his observations of the phases of Venus proved that it orbits the Sun and not the Earth.

The Catholic Church ordered Galileo to recant his claim that Earth orbits the Sun in 1633. He died under house arrest outside Florence.

His book on the subject was removed from the Church's index of banned books in 1824.

Galileo was formally vindicated by the Church in 1992.

Giordano Bruno

Bruno audaciously claimed that the Sun was just another star among an infinite universe of stars. Furthermore, those stars had planets populated with intelligent life.

He was declared a heretic and was burned at the stake in Feb 1600 A.D. in Rome.