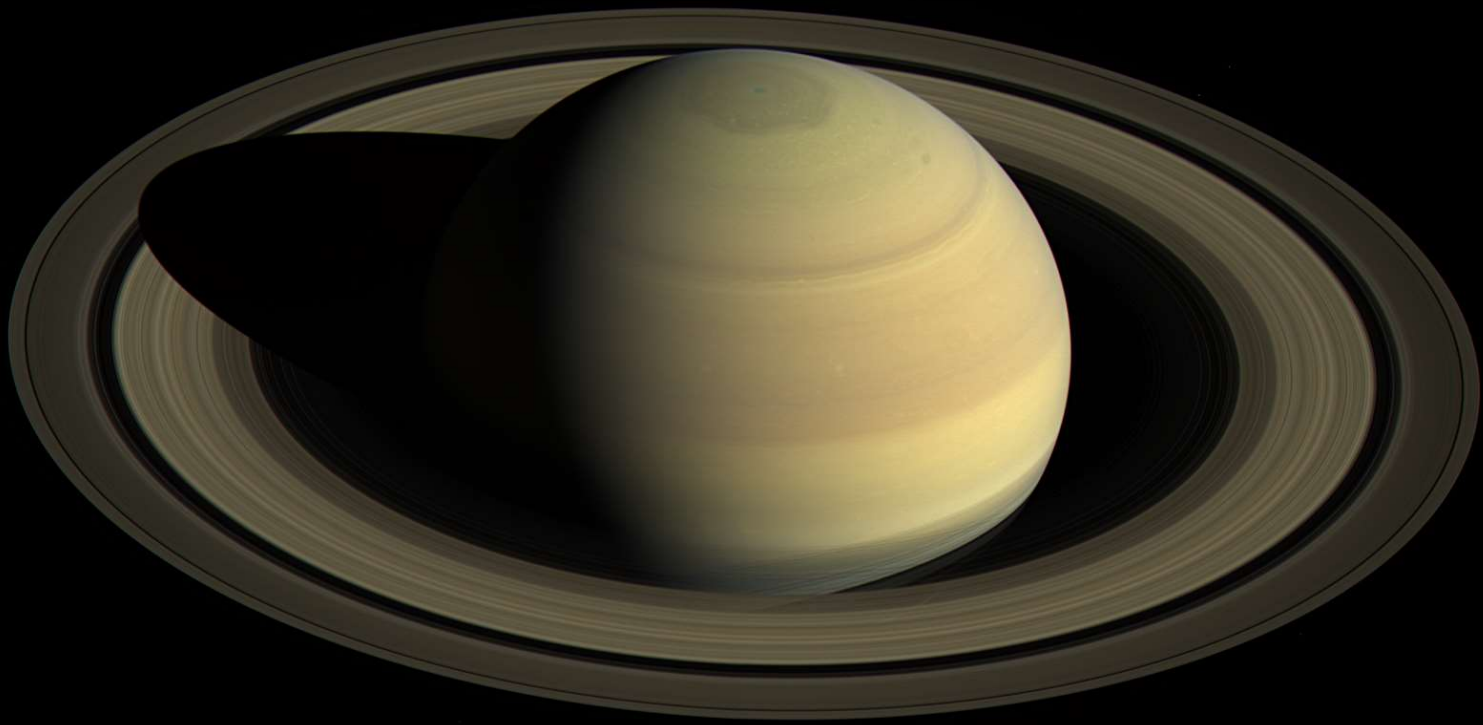
# AST 2002
# Introduction to Astronomy



**What is the phase of the Moon in the Picture taken near Sunrise above?**

A: Waning Gibbous
B: Waxing Gibbous
C: Waning Crescent
D: Waxing Crescent

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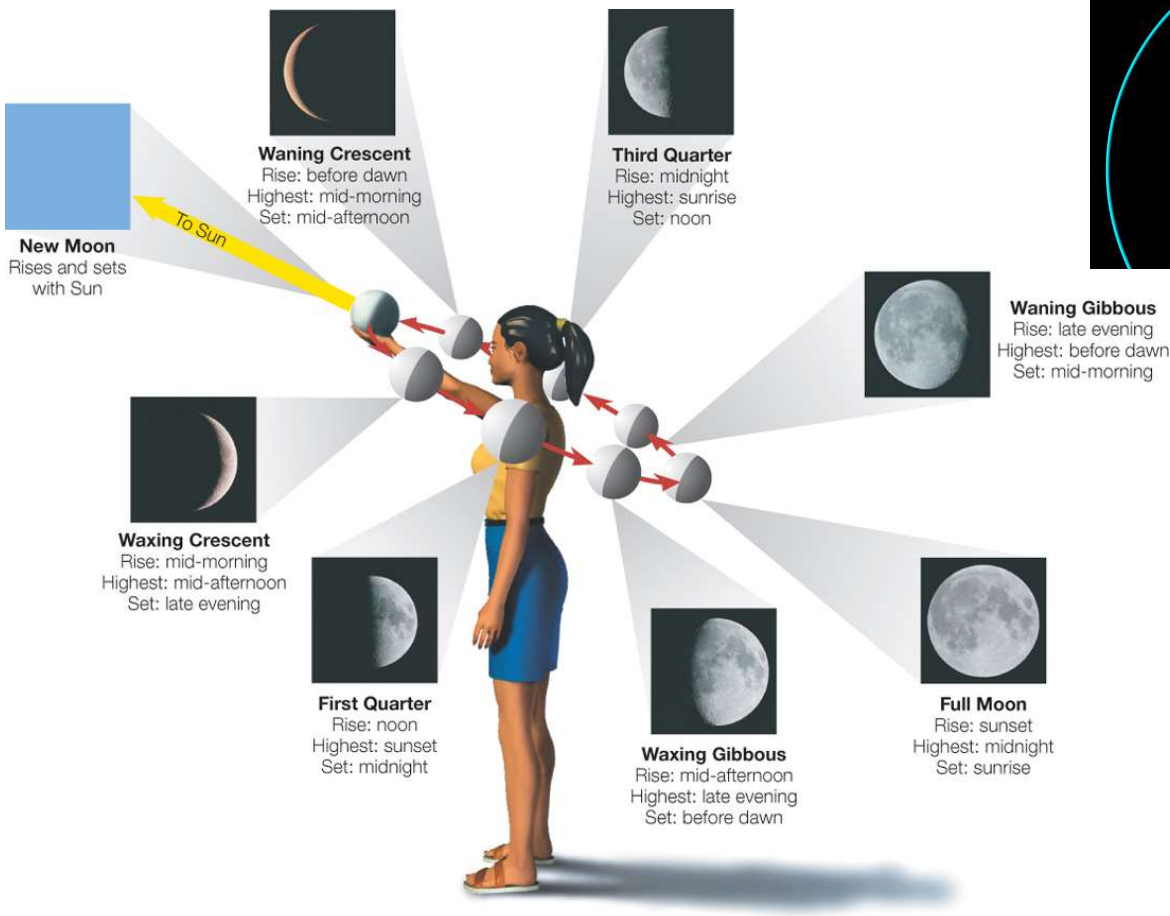
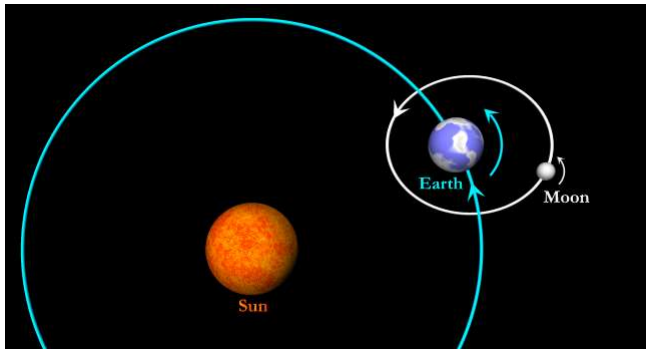
# The Phases of the Moon




Waxing: Increasing or beginning

Waning: Decreasing or ending

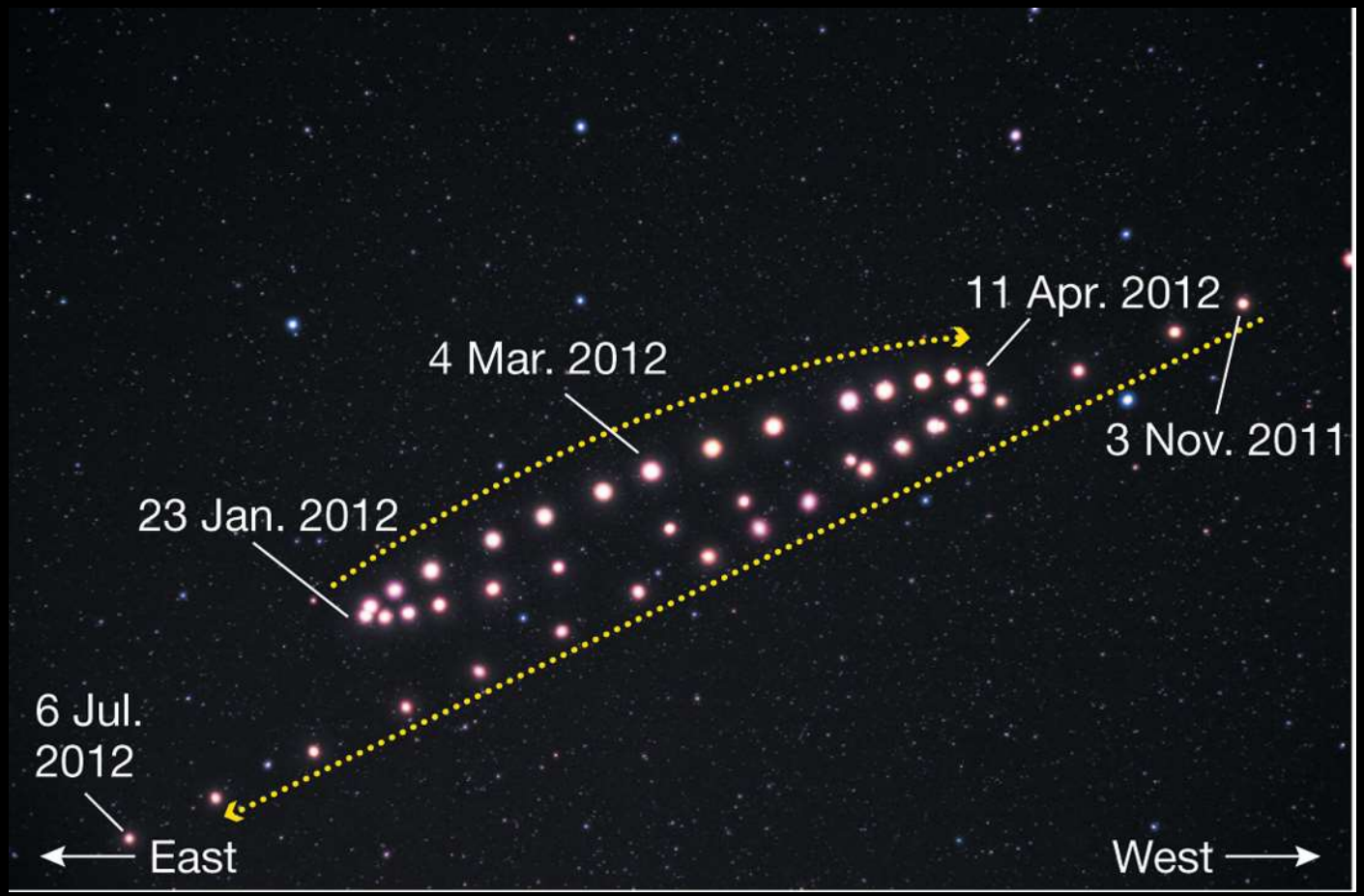
360° = 24 hrs
180° = 12 hrs
90° = 6 hrs

**Moon will rotate anti-clockwise. Start moving to the left. If it is to the left, the right side is illuminated first…**

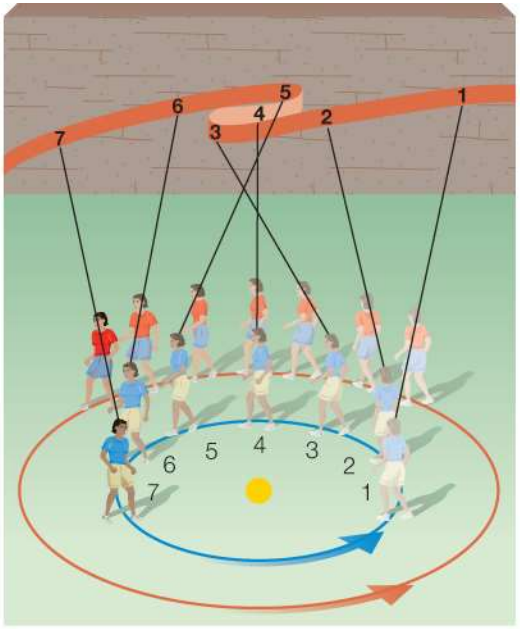
# The Wandering Planets

https://www.youtube.com/watch?v=FtV0PV9MF88

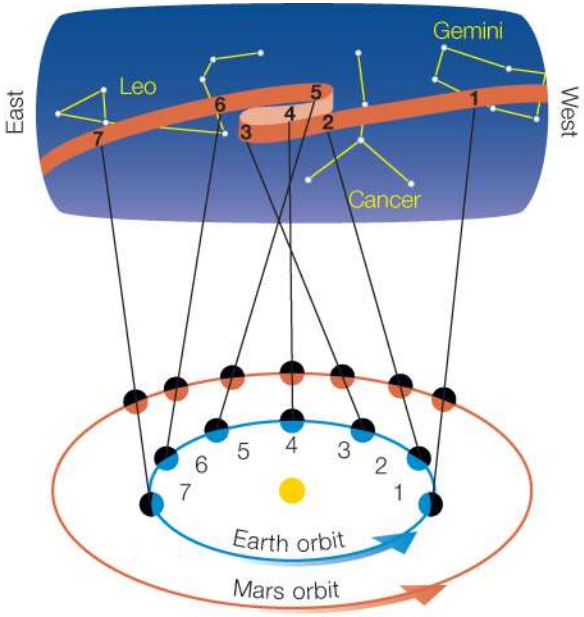
# Mars in Retrograde



# Heliocentric Explanation for Retrograde Motion




**a** The retrograde motion demonstration: Watch how your friend (in red) usually appears to move forward against the background of the building in the distance but appears to move backward as you (in blue) catch up to and pass her in your "orbit."

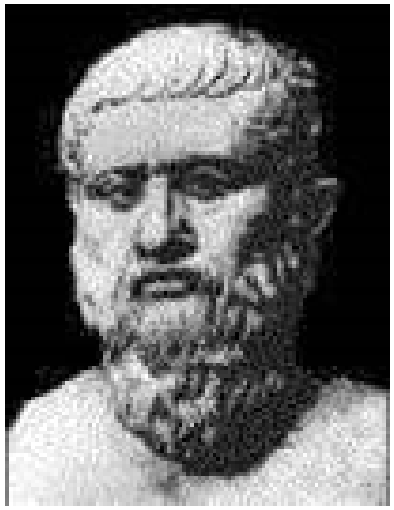



**b** This diagram shows the same idea applied to a planet. Follow the lines of sight from Earth to Mars in numerical order. Notice that Mars appears to move westward relative to the distant stars (from points 3 to 5) as Earth passes it by in its orbit.

If you are still having trouble with visualizing this concept, take a look at the video here: **https://www.youtube.com/watch?v=1nVSzzYCAYk**

# How did the Greeks explain planetary motion?

## Underpinnings of the Greek geocentric model:

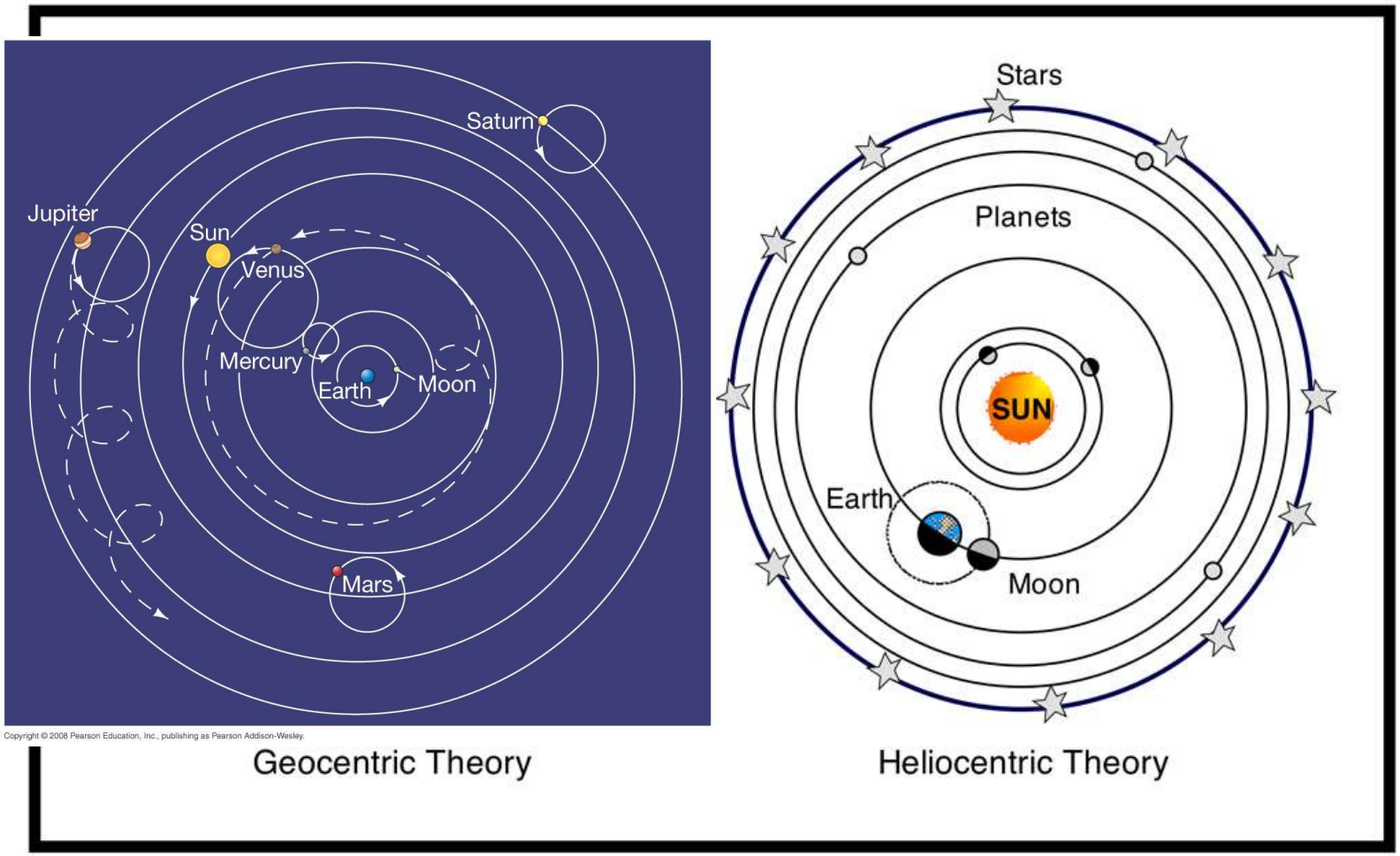


Plato,
Greek Philosopher
428 – 347 BC

- Earth is at the center of the universe
- Heavens must be "perfect“ - objects ***must*** move on perfect spheres or in perfect circles.

Aristotle,
Greek Philosopher
384 – 322 BC

# Geocentric *vs.* Heliocentric Models



# Claudius Ptolemy (AD 100-170)

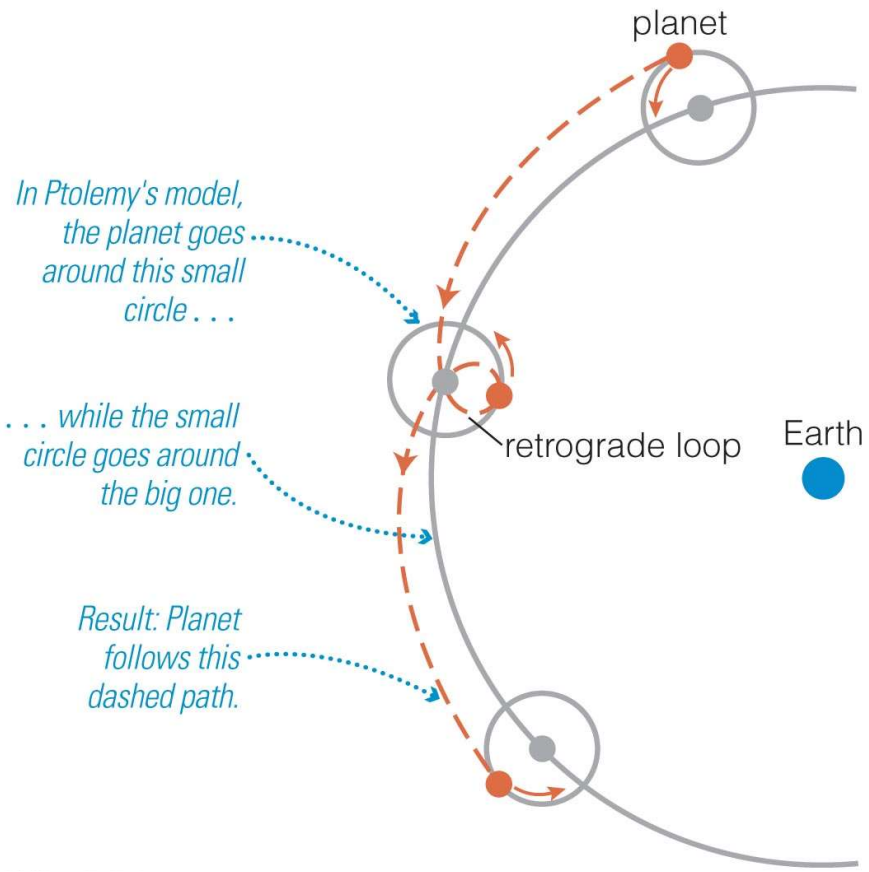
The most sophisticated geocentric model was that of Ptolemy (A.D. 100–170)—the **Ptolemaic model:**

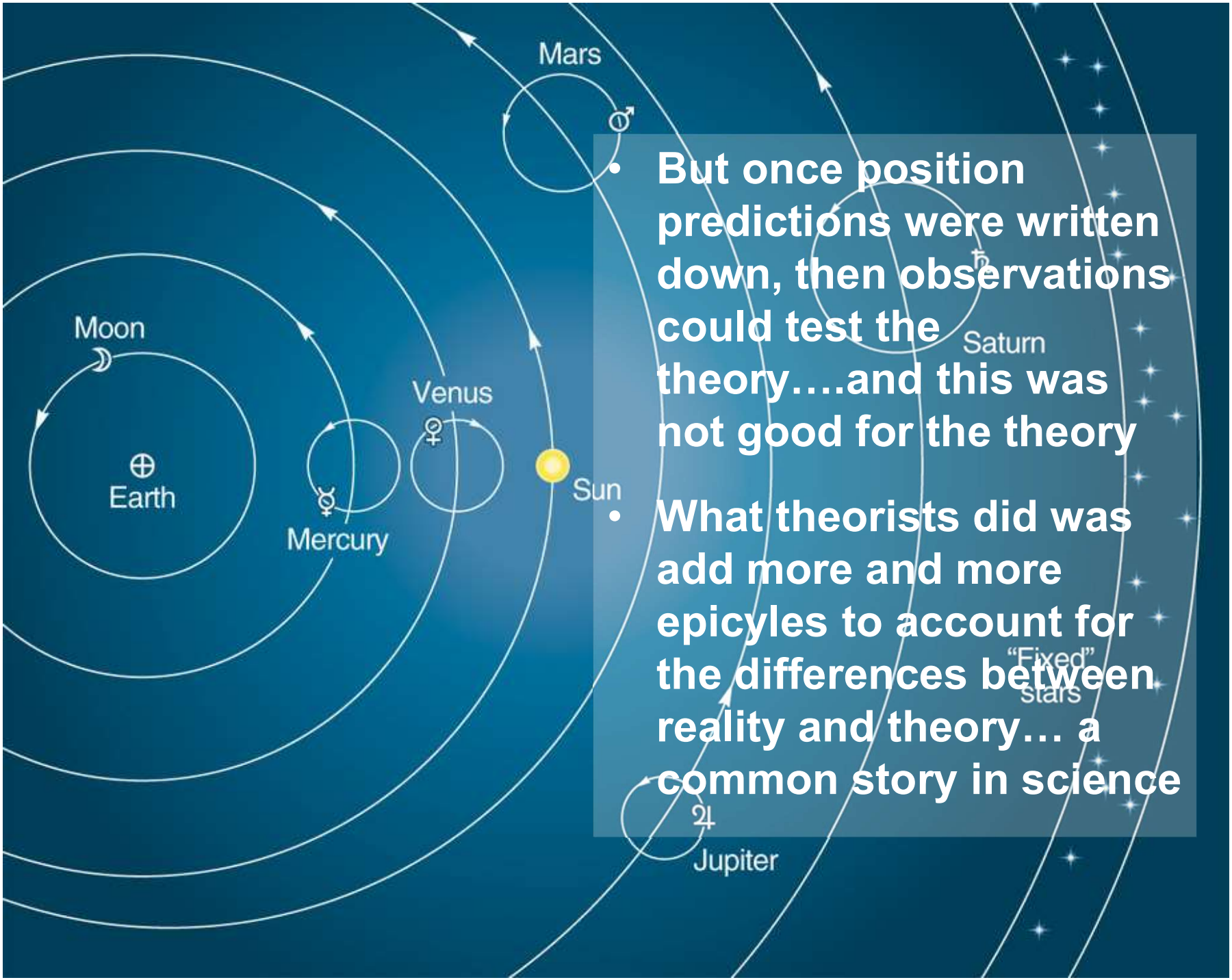
- Sufficiently accurate to remain in use for 1500 years
- Arabic translation of Ptolemy's work named *Almagest* ("the greatest compilation")
- Led to complicated Orrery Solar System models including many epicenters (circles inside of circles)


His theory fit the data, made accurate predictions!

# So how does Ptolemy's Geocentric model explain retrograde motion?

- **Earth is at center of the Universe still…**
- **Sun orbits Earth (at a distance between Venus and Mars)**
- **Planets orbit on small, *perfect circles* whose centers orbit the Earth on larger circles**
  - **the small circles are called epicycles**
- **This explained retrograde motion**

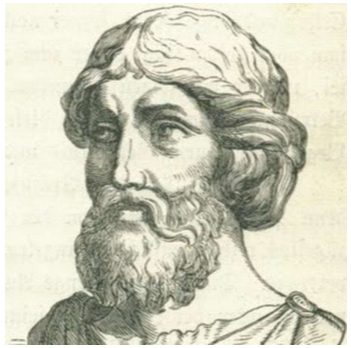




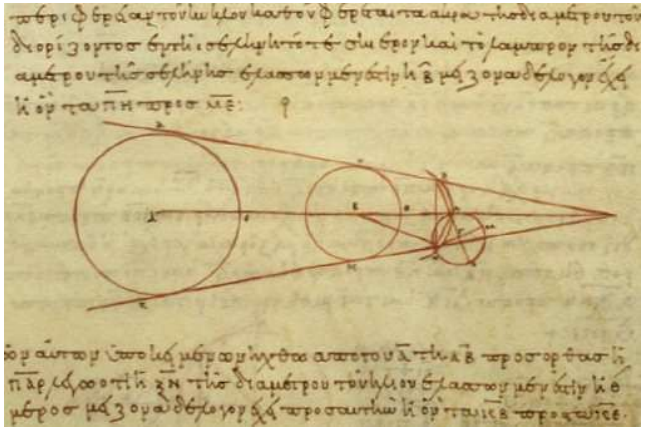

- But once position predictions were written down, then observations could test the theory….and this was not good for the theory
- What theorists did was add more and more epicyles to account for the differences between reality and theory… a common story in science

# Aristarchus of Samos

Greek Astronomer/Mathematician, 310-230 BC.



- Presented the first known model that placed the Sun at the Center of the Known Universe, with Earth revolving around it, and put the planets in the correct order revolving around the Sun.
- Also estimated that the Sun was 18-20 times more distant than the Moon (actually ~400 times)



**Unfortunately, the idea was rejected. Why?**

Difficult to Imagine the Earth is Rapidly Rotating, or Moving at Great Speeds

- Should be noticeable? E.g., a Great wind as the Earth Rotates…

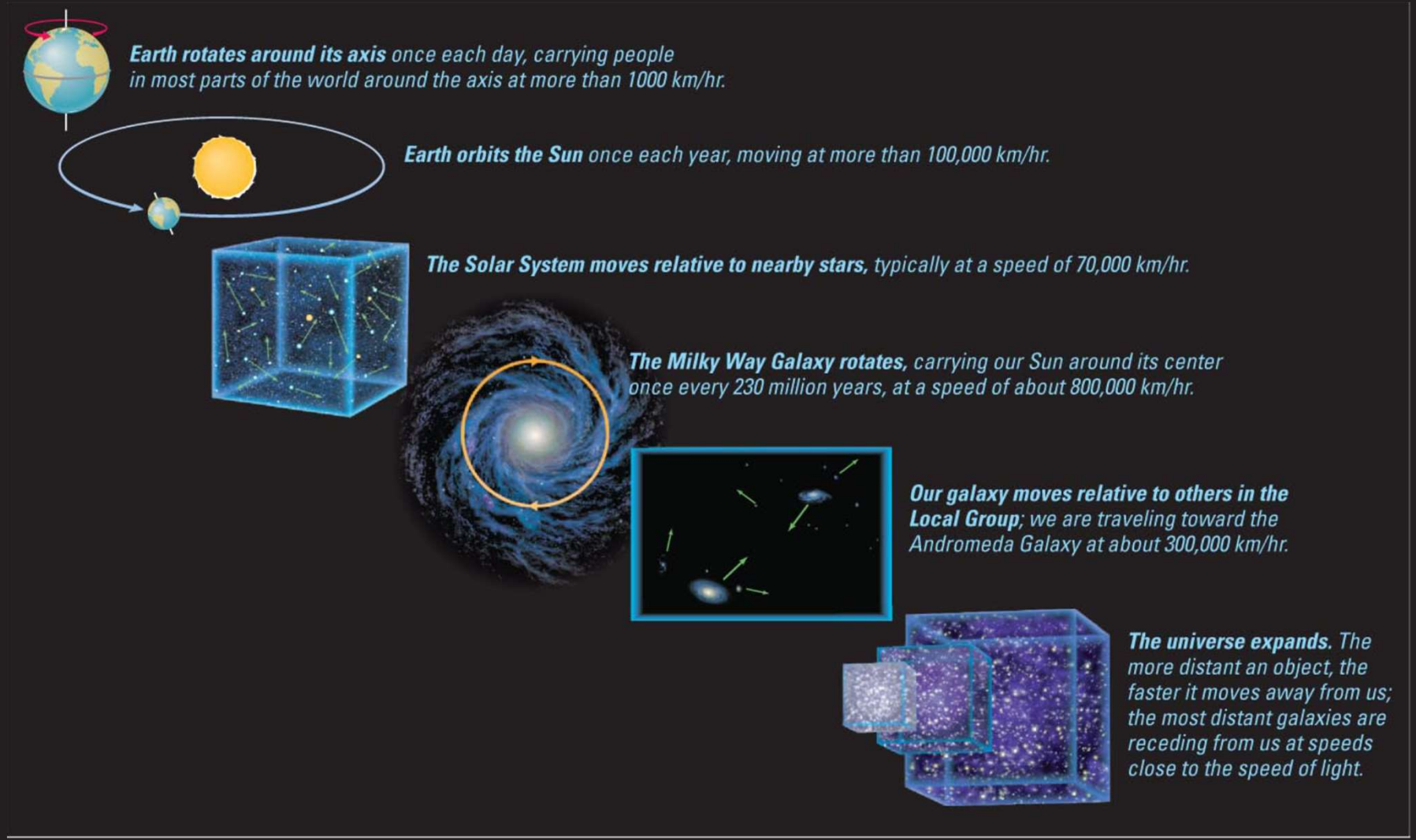
Either:

**a)** Earth orbits the sun, but the stars are so far away that stellar parallax is not detectable to the naked eye

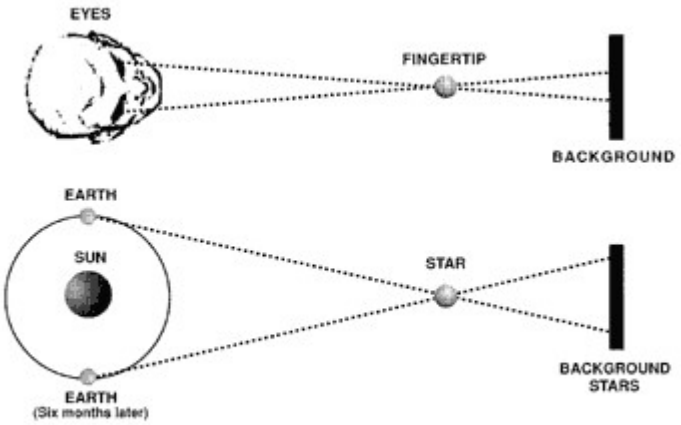
**Or, b)** There is no stellar parallax because Earth is stationary at the center of the Universe

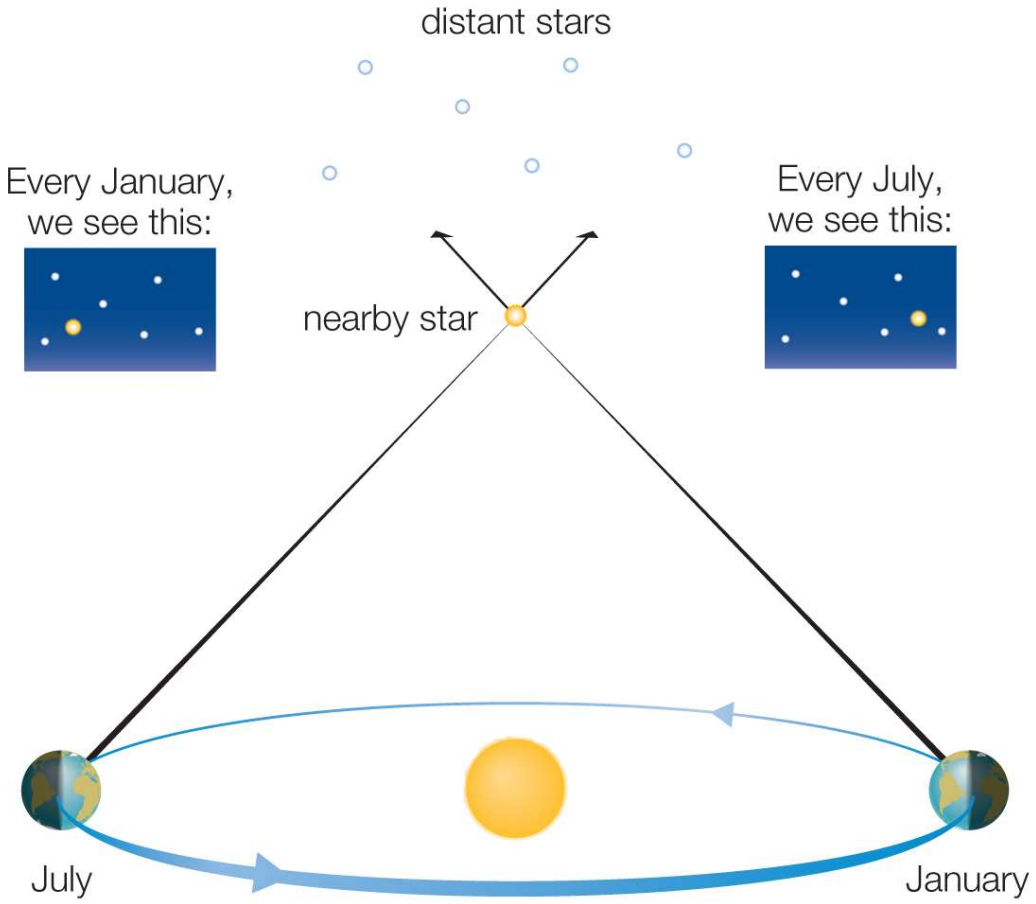
# Spaceship Earth

https://www.youtube.com/watch?v=ucLYUYDhgos **for a visualization...**



# What is Stellar Parallax?

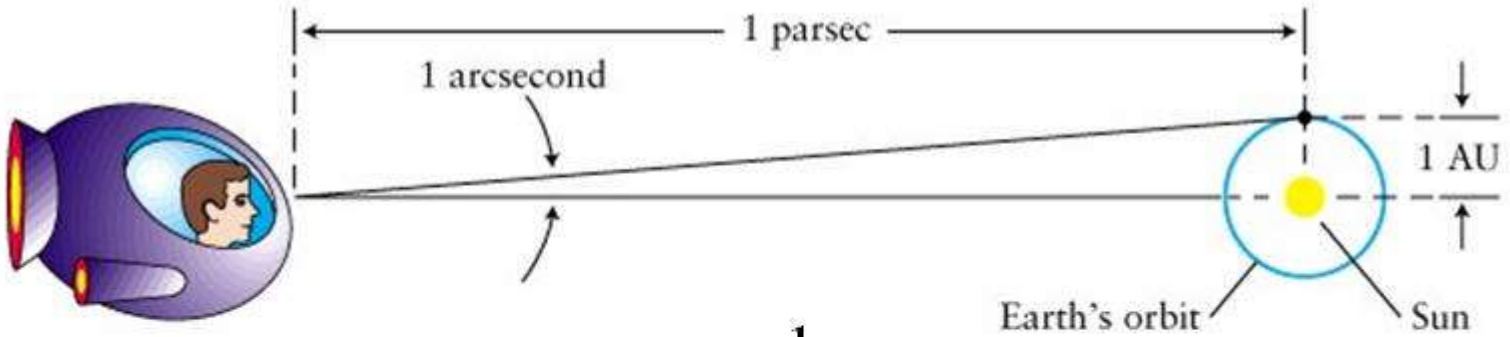



*If some stars are closer than others, then they should move an appreciable amount when the Earth is at opposite sides of the Sun, ... 'if' the heliocentric model is correct...*

# How can we Measure the Distance to the Stars?

**Definition of a Parsec:** **(again, uses the small angle approximation which makes the math a little bit easier!)**




$$d = \frac{1}{p}$$

***d*** is in parsecs when ***p*** is in arcseconds

1 parsec = 3.26 light-years

# Example Calculation: What is the Parallax for our nearest star?

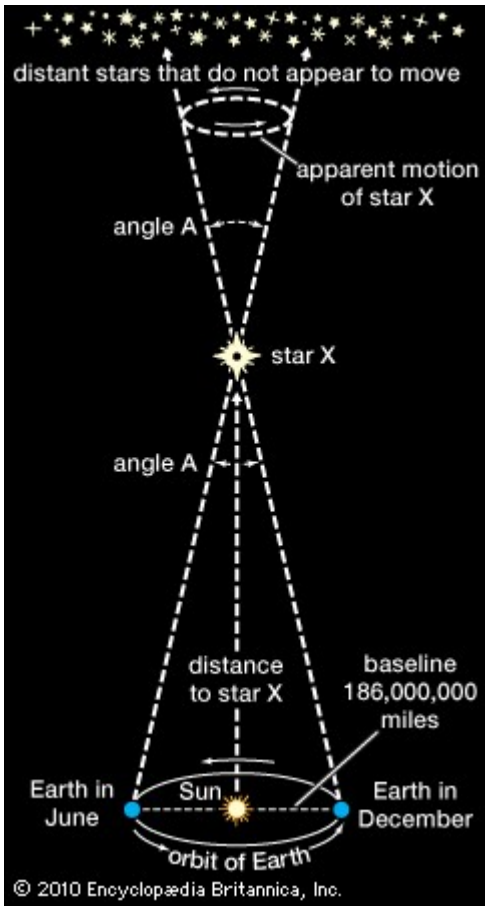
**Alpha Centauri has a parallax of 0.76813″, what is it's distance?**

$$d = \frac{1}{p} = \frac{1}{0.76813}$$

**d ~ 1.302 parsecs, or 4.24 light years**

**Remember, 1 arcsecond = 1/3600 of a degree!**

https://www.britannica.com/science/star-astronomy#ref510284 for more info…



# Thought Question – iClickers Ready!

Which of the following is NOT a fundamental difference between the geocentric and heliocentric models of the solar system?

A. is stationary in the geocentric model but moves around the Sun in Sun-centered model.

B. Retrograde motion is real (planets really go backward) in the geocentric model but only apparent (planets don't really turn around) in the Sun-centered model.

C. Stellar parallax is expected in the Sun-centered model but not in the Earth-centered model.

D. The geocentric model is useless for predicting planetary positions in the sky, whereas even the earliest Sun-centered models worked almost perfectly.

# Thought Question

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# It is Clear that Astronomy has had a strong influence on our Civilization

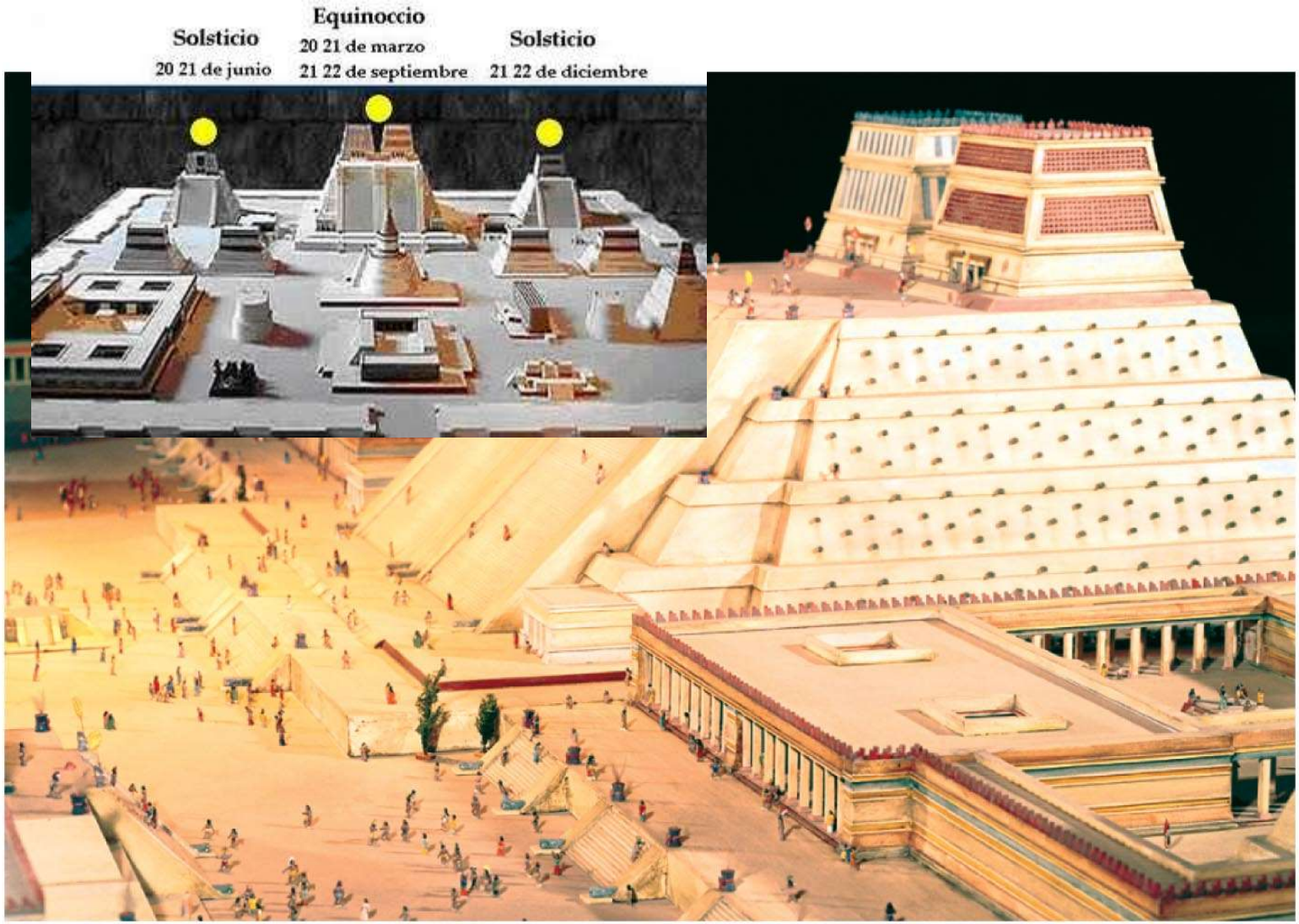
**Years:** **How long it takes for the Earth to Orbit the Sun (or vice versa!)**
**Months:** **How long it takes for the moon to orbit the Earth**

*The seven days were originally linked directly to the seven objects. The correspondence is no longer perfect, but the pattern is clear in many languages; some English names come from Germanic gods.*

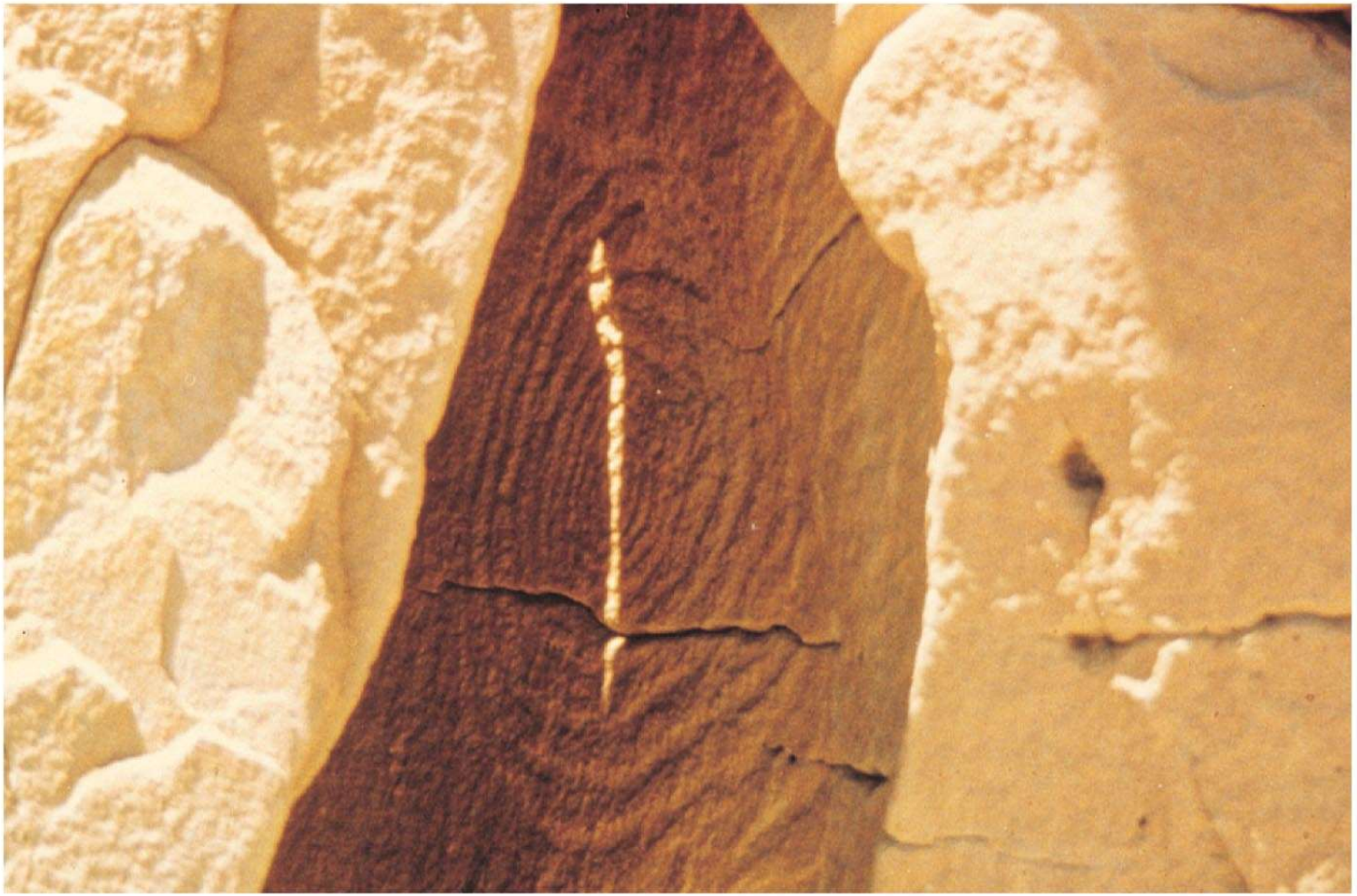
| Object | Germanic God | English | French | Spanish |
|---|---|---|---|---|
| Sun | — | Sunday | dimanche | domingo |
| Moon | — | Monday | lundi | lunes |
| Mars | Tiw | Tuesday | mardi | martes |
| Mercury | Woden | Wednesday | mercredi | miércoles |
| Jupiter | Thor | Thursday | jeudi | jueves |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

Scotland: 4000-year-old stone circle; Moon rises as shown here every 18.6 years.


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



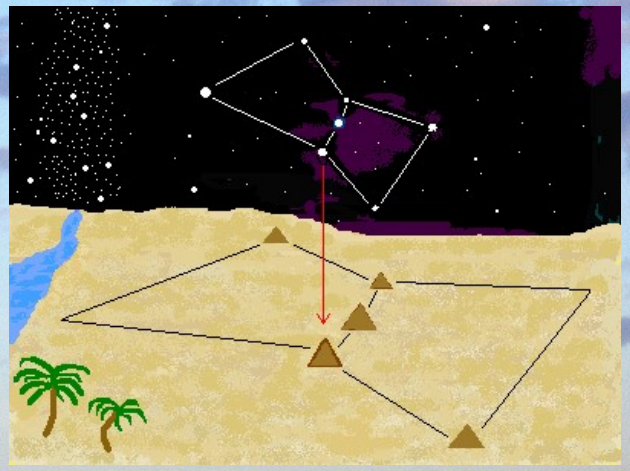

# Mexico: Model of the Templo Mayor, (est. after 1325)



SW United States: "Sun Dagger" marks summer solstice

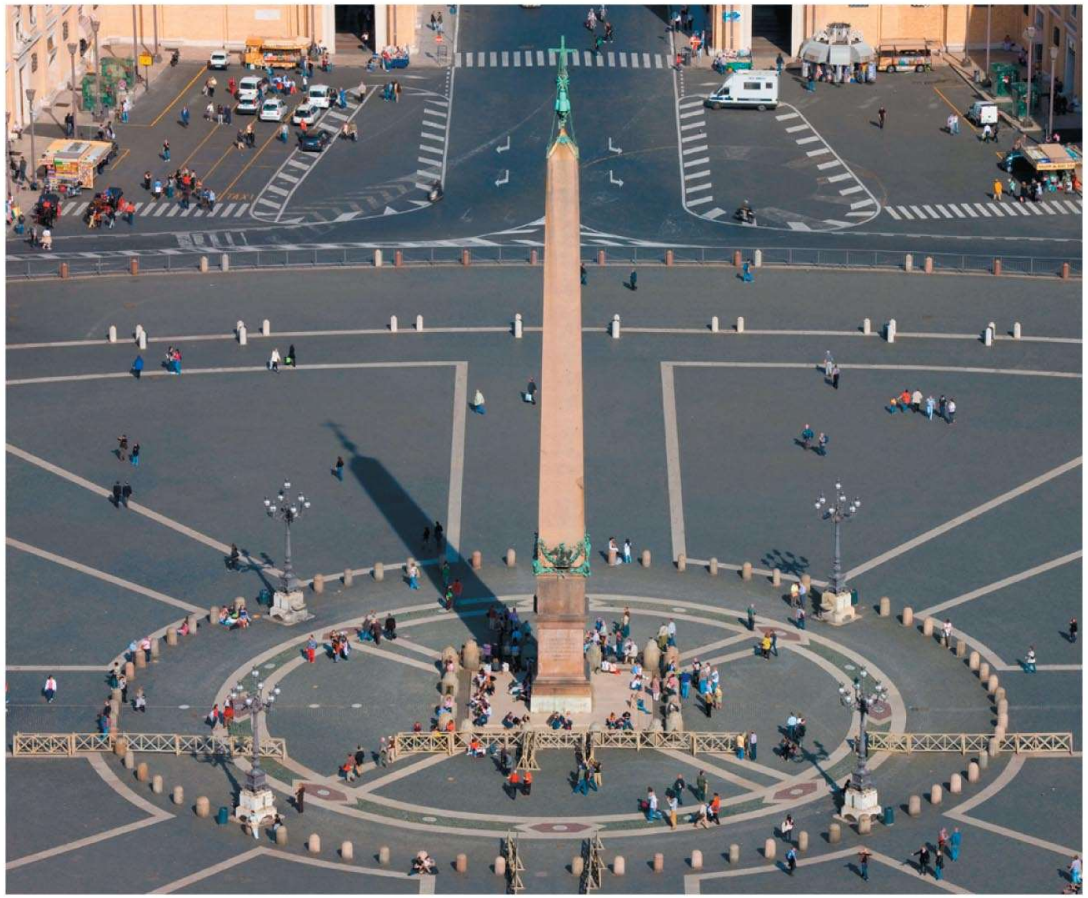

# Machu Picchu, Peru (1450-1460): Structures aligned with solstices. Temple of the Sun at Winter Solstice

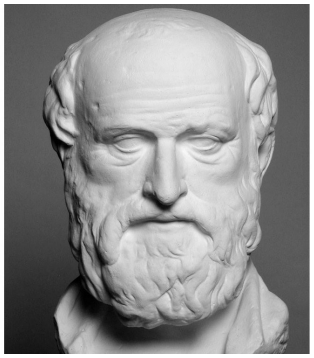
# Pyramids of Giza (~4500 years old)

# Obelisks all over the world, many in Egypt.

- Shadows tell time of day.



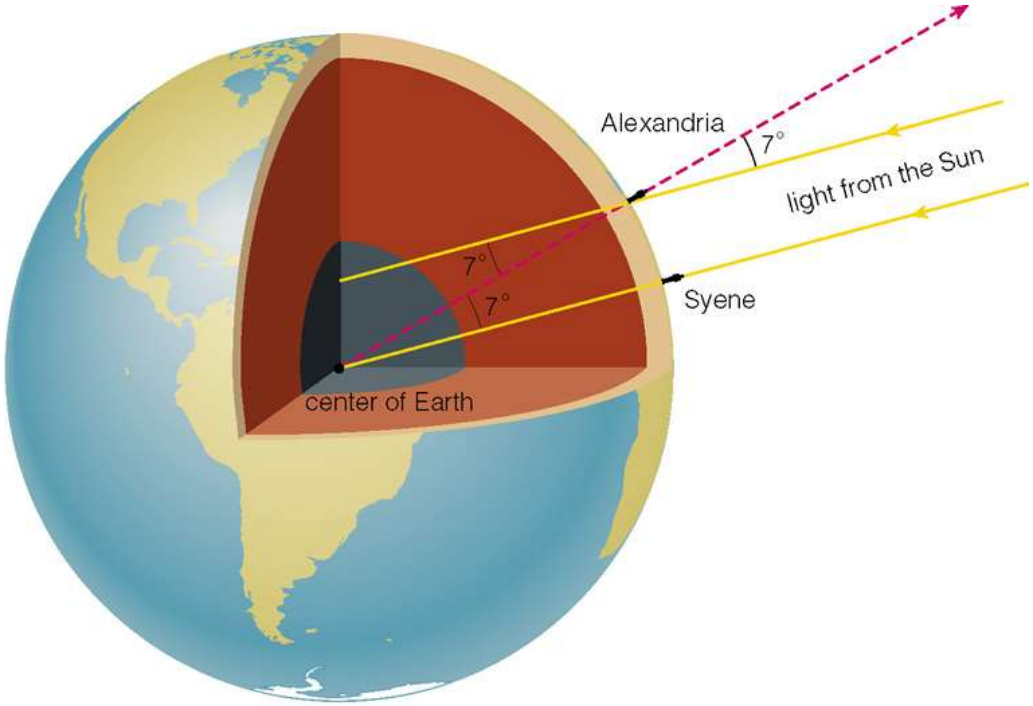


# Eratosthenes (276 - 195 BC)

**He measured the circumference of the Earth.**

**The Sun is at the zenith in the city of Syene at noon on the summer solstice.**

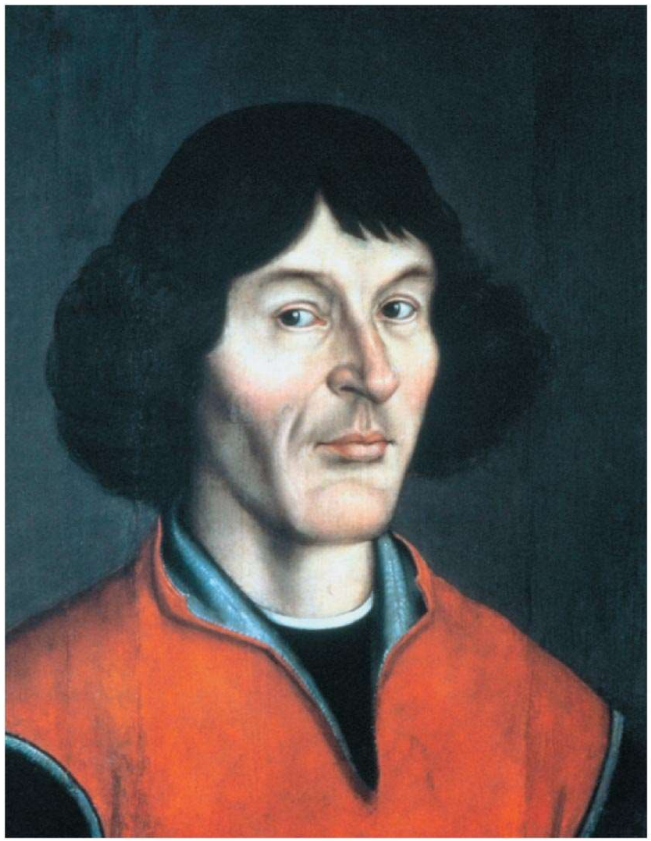
- **But at the same time in Alexandria, it is 7° from the zenith.**




- **Eratosthenes inferred that Alexandria was 7° of latitude north of Syene.**
- **The distance between the two cities is 7/360 times the Earth's circumference.**
- **His result of 42,000 km is very close to the right number: 40,000 km.**

# How did Copernicus, Tycho, and Kepler challenge the Earth-centered model?

Copernicus (1473–1543)





- Copernicus proposed the Sun-centered model (circulated since 1514, published 1543).
- He used the model to determine the layout of the solar system (planetary distances in AU).

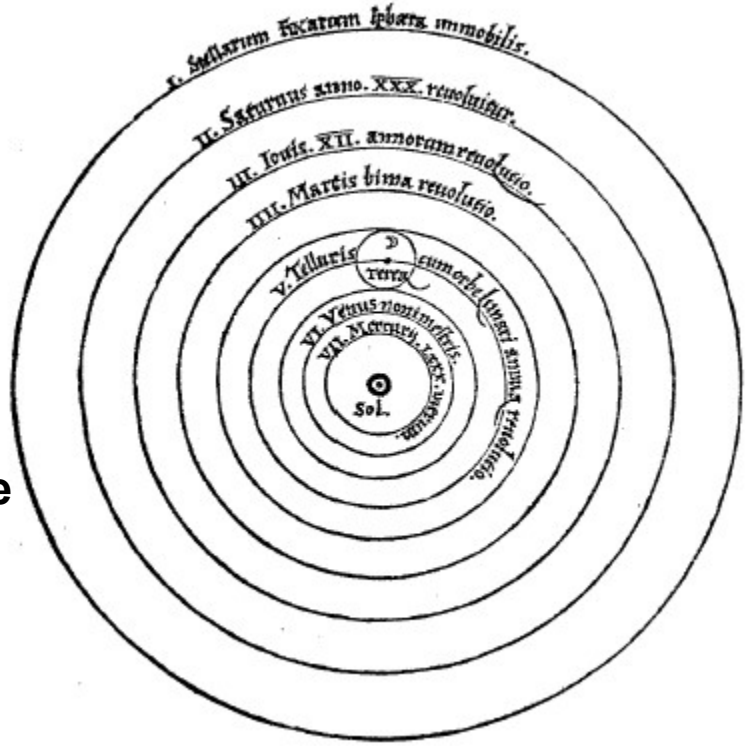
But . . .

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

## His observations made it clear that Ptolemy theory did not work very well

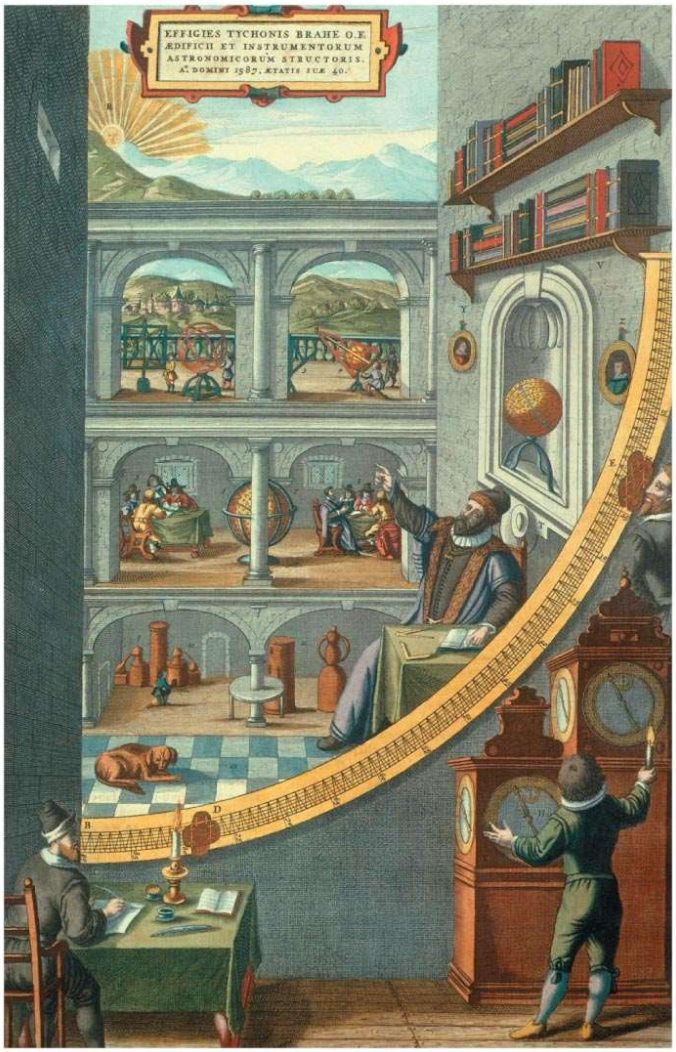
- His solution was to put the Sun at the center.
- The math was much simpler and the results much better
  - The Sun was at the center of the solar system
  - The stars were very distant
  - Earth orbits like any other planet
  - Inferior planet orbits are smaller
  - Retrograde motion occurs when we "lap" Mars & the other superior planets
  - The annual cycle of the Sun is caused by the Earth's orbit
- Waited until near Death before publishing
  - Written *very carefully* so as to not upset the Church (inquisitions, burning at the stake?)

"that *if* the earth were in motion *then* the observed phenomenon would result." (so he could plausibly deny he believed it)




- Didn't obtain much traction at the time
  - Written in Latin
  - Didn't work very well because it still used perfect circles, required epicenters as did Ptolemaic models

# Tycho Brahe (1546–1601)






- Brahe compiled the most accurate (1 arcminute) naked eye measurements ever made of planetary positions.
- He still could not detect stellar parallax, and thus still thought Earth must be at the center of the solar system (but recognized that other planets go around the Sun).
- He hired Kepler, who used Tycho's observations to discover the truth about planetary motion.

# Pause for Science…

## … What can you tell me about the Moon?

**There are Dark and lighter regions**

**Lighter regions are more heavily cratered.**

- More small impacts than large Impacts (if you look close)
- Darker regions seem to lie within large craters
- Darker regions are younger, possible basaltic flows…

**Brightest areas come from more recent craters**

- Ejecta lying on top are brightest (e.g., Tycho's crater)
- Lighter regions seem to darken over time…

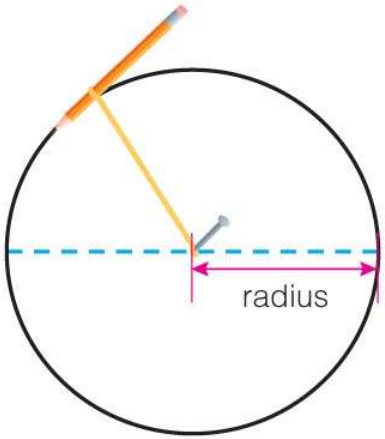
# Johannes Kepler
## Astrologer (1571–1630)



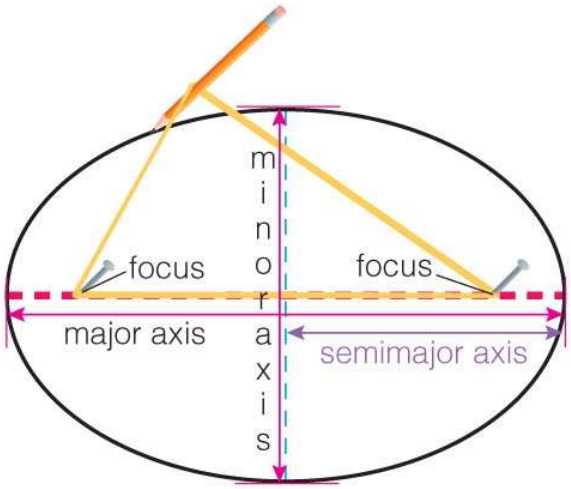

- Kepler first tried to match Tycho's observations with circular orbits.
- But an 8-arcminute discrepancy led him eventually to replacing planets moving in perfect circles with ellipses. He knew Tycho would not have been so inaccurate…

*"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."*

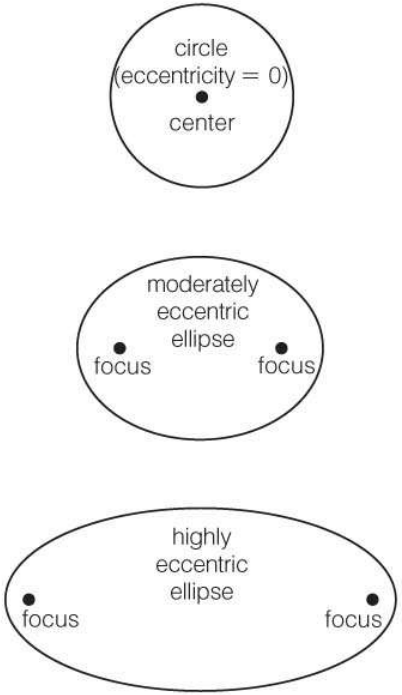
# What is an ellipse?




a Drawing a circle with a string of fixed length.




b Drawing an ellipse with a string of fixed length.




c Eccentricity describes how much an ellipse deviates from a perfect circle.

# An ellipse looks like an elongated circle.

End of Todays Lecture