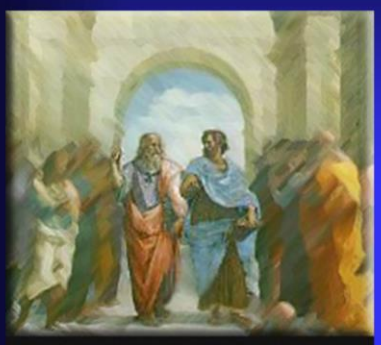
A Bit of History



Plato (left) and Aristotle (right) in Athens.

Ancient "Greece":

- *Geo*centric model of the heavens

Antikythera device

Before the Greeks, people used motions in the heavens as predictors of terrestrial events.

"The Greeks" created the first theoretical models attempting to explain the mechanisms behind natural phenomena.

As far as we know, they were the first to do this.

(The Western world calls Greece the birthplace of modern science, but really this is because we call anyone colonized/conquered by Greece "Greece". Really we're probably talking primarily about Egypt and Mesopotamia, e.g. Babylonian astronomy.) Much of this was collected together (read: stolen and co-opted) by those in Greece.

Science, as scientists understand it, is not fundamentally European in origin. See Wikipedia's entry: https://en.wikipedia.org/wiki/History_of_scientific_method#Emergence_of_inductive_experimental_method

The image on the right is the Antikythera device, an astronomical computer found in the Mediterranean Sea.

Greek Models:
The heavens are perfect and unchanging.
~Aristotle

Geocentric model:

- Earth at the center
- Sun, Moon, stars, and planets affixed to crystalline rotating spheres.

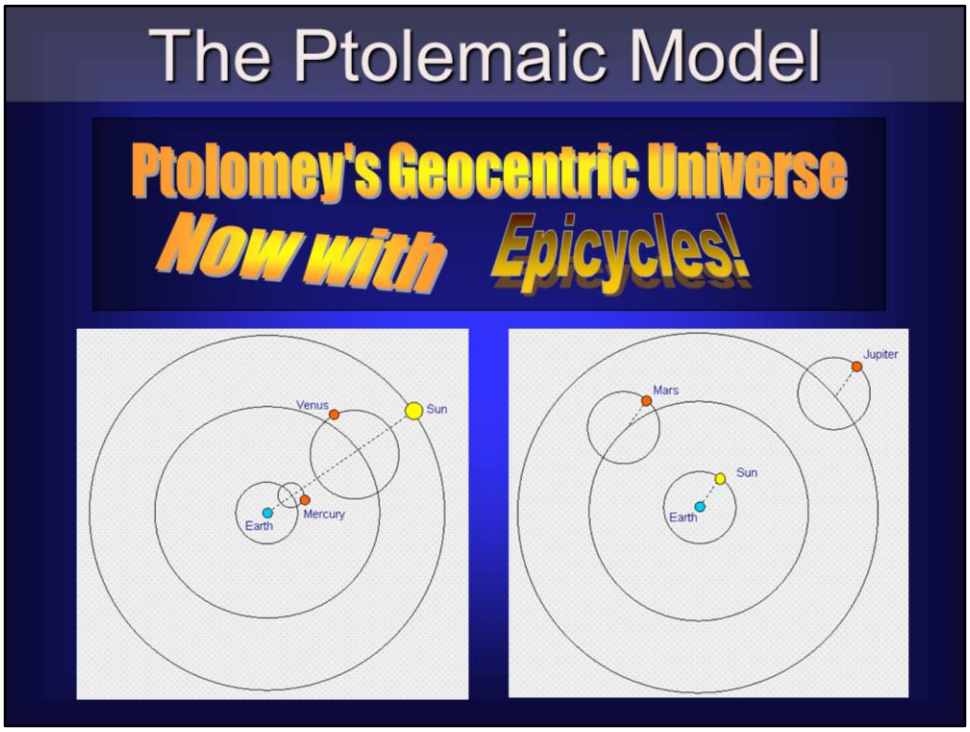
Ptolemy:
Used epicycles (circles on circles) to reproduce retrograde motion
Predicted planetary positions to within a few degrees – the best yet!
Extremely complex (but hey it's working!)
Used for about 1500 years. (because it's working!)
Still geocentric

Image credits: Wikipedia creative commons
https://en.wikipedia.org/wiki/Edwin_Smith_Papyrus, Qatar Postage stamp

There is a good history of science class here on campus; check it out.

الحسن بن الهيثم

Al-Hazen made theoretical physics a thing; he worked on optics, mathematics, and astronomy. Lived 965-1040AD (200 years before the Renaissance!), born in what is now Iraq and lived in Cairo Egypt later.
What do I mean by *theory*? Remember: we are talking about supporting hypotheses through observation.



The Ptolemaic model is the first solar system model to attempt accurate predictions of planetary positions.

By adjusting the rates of each main orbit (deferent) and

each epicycle, the model could be tuned to fit observations

Ptolemy's model is RIDICULOUSLY complex.

It took a team of mathematicians many years to complete a table of predictions using this framework.

Although more accurate than Aristotle's crystalline spheres, it was only accurate to within about 10 degrees.

(Ptolemy was probably ethnically Greek living in Egypt, though may have been Egyptian. He definitely used Babylonian astronomy in his works.)

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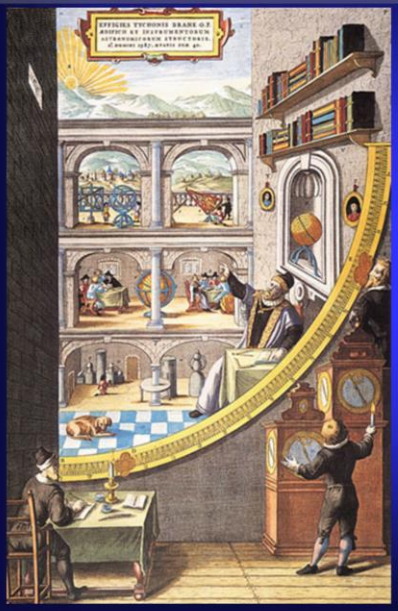

We need a new model:

- Copernicus: *Helio*centric model…but it's not more *accurate*
- Tycho Brahe: precise observations
- Kepler: Hey, it turns out … Copernicus is right!

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Heliocentric models
Copernicus:
Uh-oh, Ptolemy's model is really inaccurate now (but hey we made it, like, 2,000 years!)
Sun centered model, 1543

- Simple retrograde solution
- Simple orbital period calculation
- Position predictions still inaccurate. Crud. Well the model itself is simpler so by occam's razor….

Tycho Brahe:
We need better observations. Took two decades of very precise measurements of planetary positions. What do I mean by "very precise"? Accuracy to within 1 minute of arc
What is one minute of arc? The angular diameter that a quarter would appear to be from a distance of nearly a football field away! He did these observations *by eye*, how crazy is that?

Kepler:

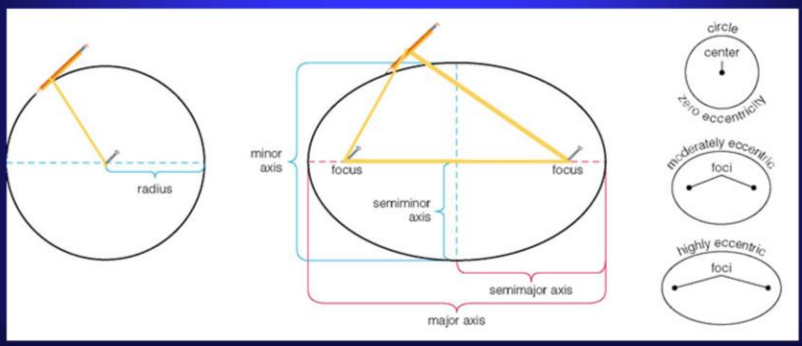
- A student of Tycho
- Studied Tycho's data
- Discovered three empirical relationships
- Believed Copernicus
- Suggested that the Sun exerts a force on the planets.

Kepler was a contemporary of **Galileo**! We'll talk more about Galileo in a minute, after we see what Kepler said.

Kepler's First Law

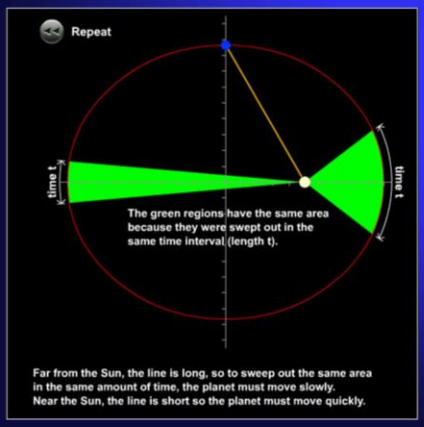
Down with circles!

Orbits are ellipses



Kepler's Second Law

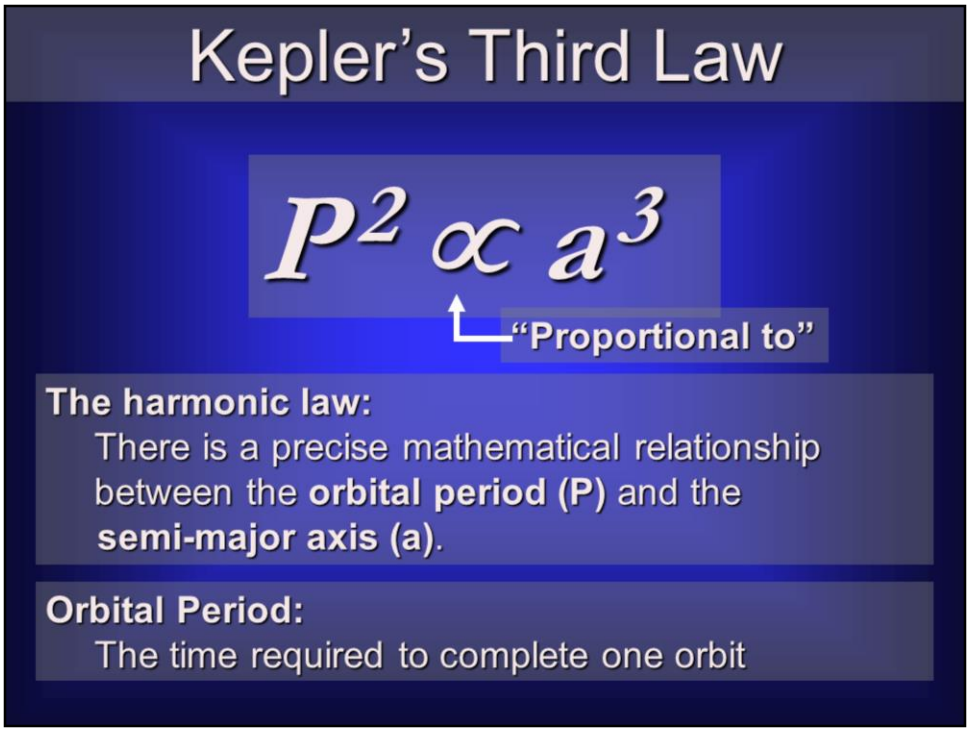
Perihelion: Point in an orbit closest to the Sun.
Aphelion: Point in an orbit furthest from the Sun.



Planets move:

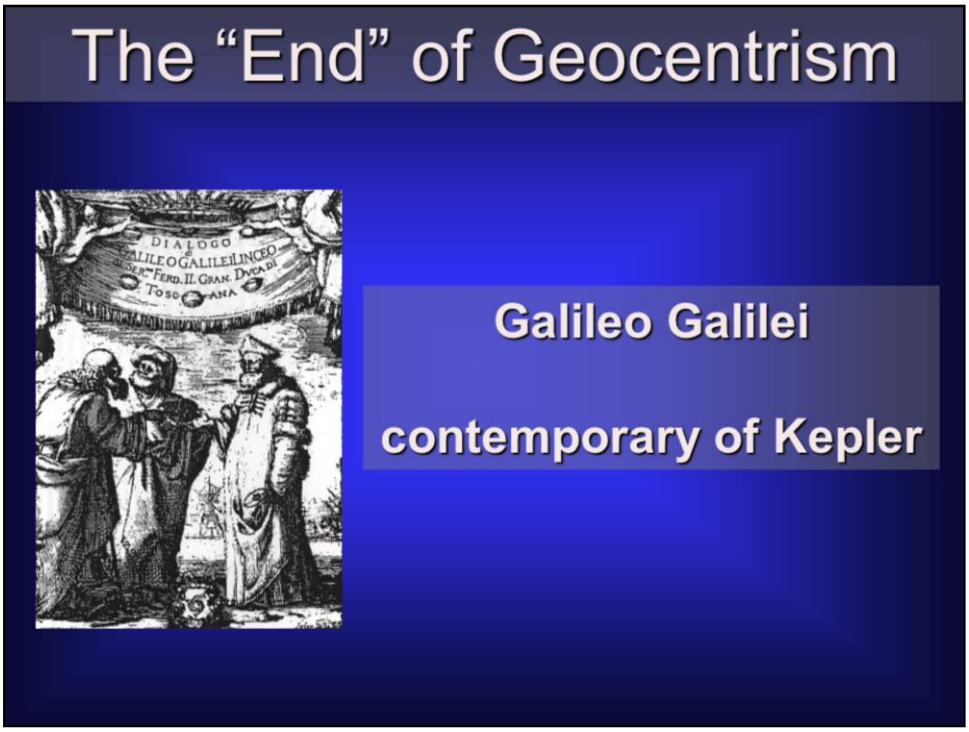
- Fast at perihelion
- Slow at aphelion

Equal areas in Equal times



But what does that "proportional" mean?
If we use Period (P) in years and distance (a) in AU, the constant is 1.
What does that constant *mean*? It must have some physical significance…

But remember, **Kepler's laws are empirical** – based only on observation. It took someone else to figure out what that "k" means.
We'll come back to it after we talk about Newton's laws.



Galileo said that objects in motion stay in motion before Newton did!

Galileo observes:

The moon's surface is much like the Earth's with mountains, canyons and Craters.

The Sun has sunspots that come and go

Galileo observes:

Jupiter has satellites of its own.

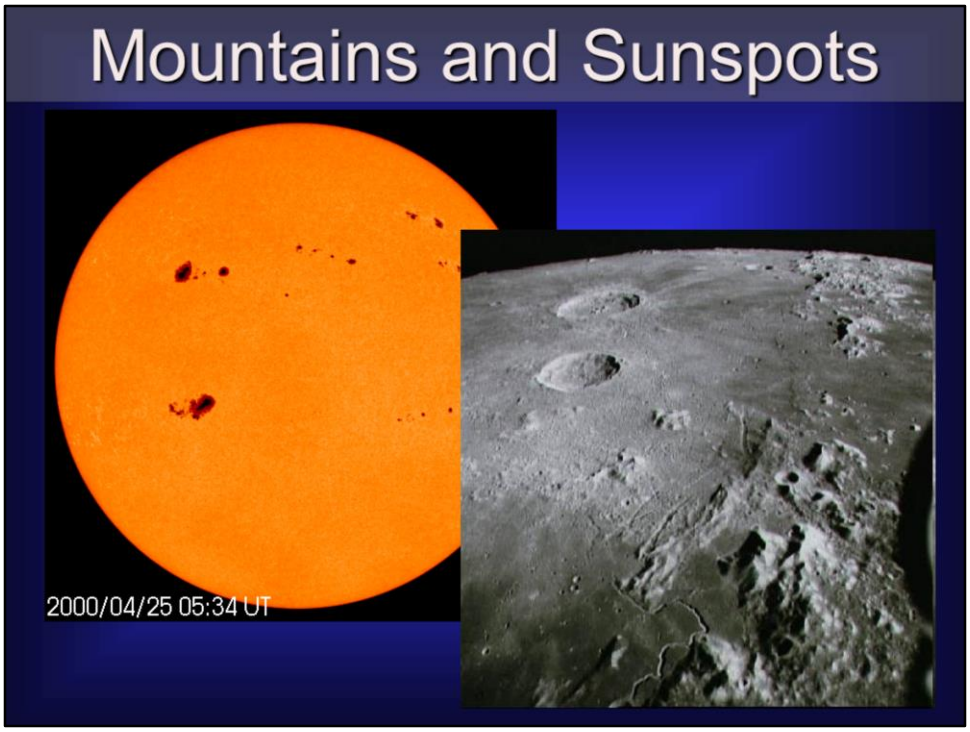
These "moons" are NOT going around the Earth

Galileo observes:

Venus and the Earth's Moon have (different) phases.

The only plausible explanation is that Venus and the Earth orbiting the Sun

AND the orbit of Venus is interior to the orbit of Earth.



Aristotle says:

The heavens are perfect and unchanging.

The Sun, the Moon, the planets, and the stars are perfect spheres.

The Earth is the realm of the imperfect

Galileo observes:

The moon's surface is much like the Earth's with mountains, canyons and Craters.

The Sun has sunspots that come and go

Aristotle says:

The Earth is at the center and EVERYTHING goes around it.

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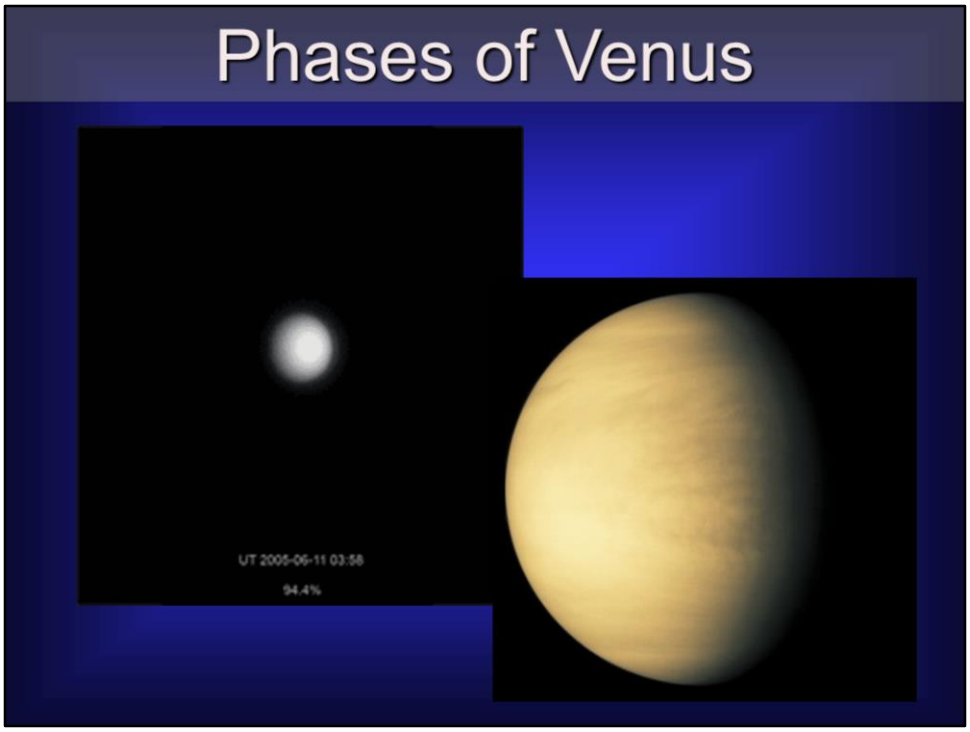

This is the KILLER observation.

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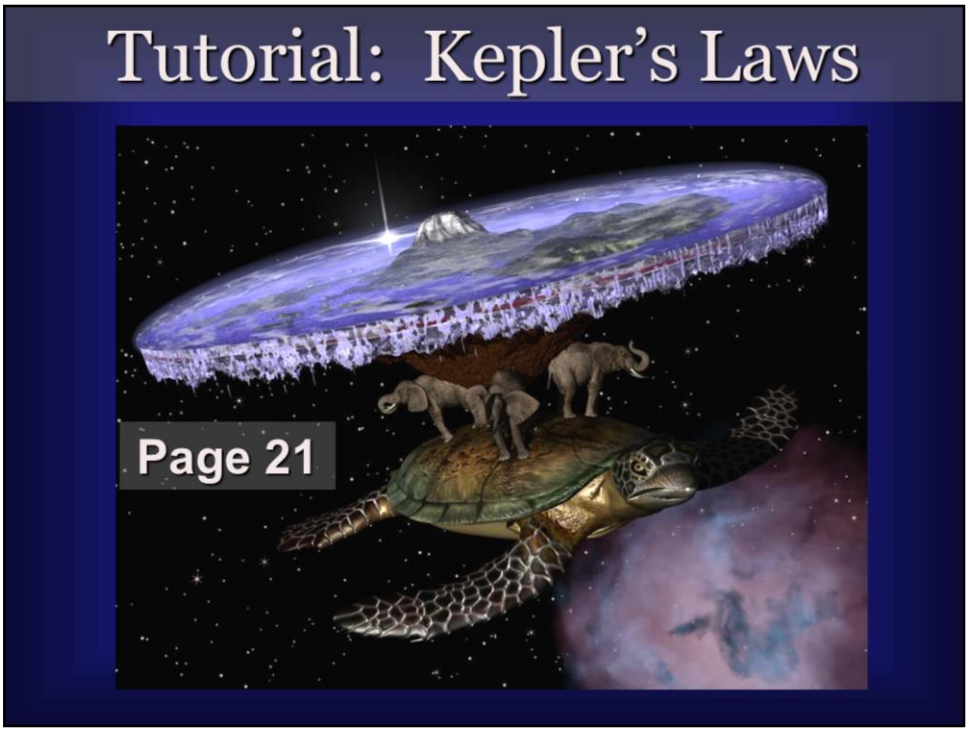


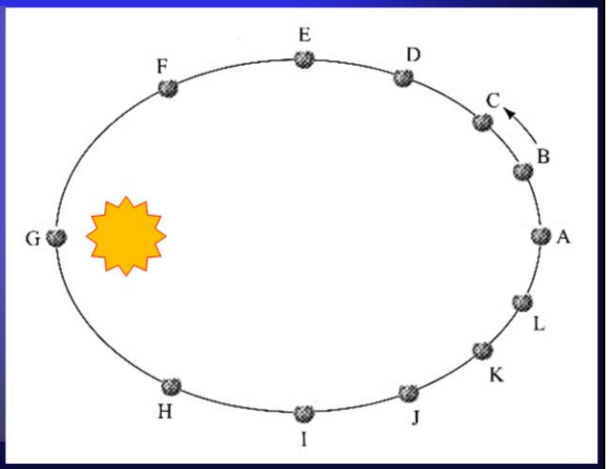
Class discussion:
Page 21; Kepler's 2nd Law tutorial
SKIP Page 22
Page 23: Kepler's 2nd Law tutorial
Page 24: Kepler's 2nd Law tutorial

Ask: Which one changes the most (percentage-wise)?

Tutorial: Kepler's 3rd Law pages 25 and 26 only

Which has the highest speed?

1) A
2) C
3) G
4) I
5) None of these



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