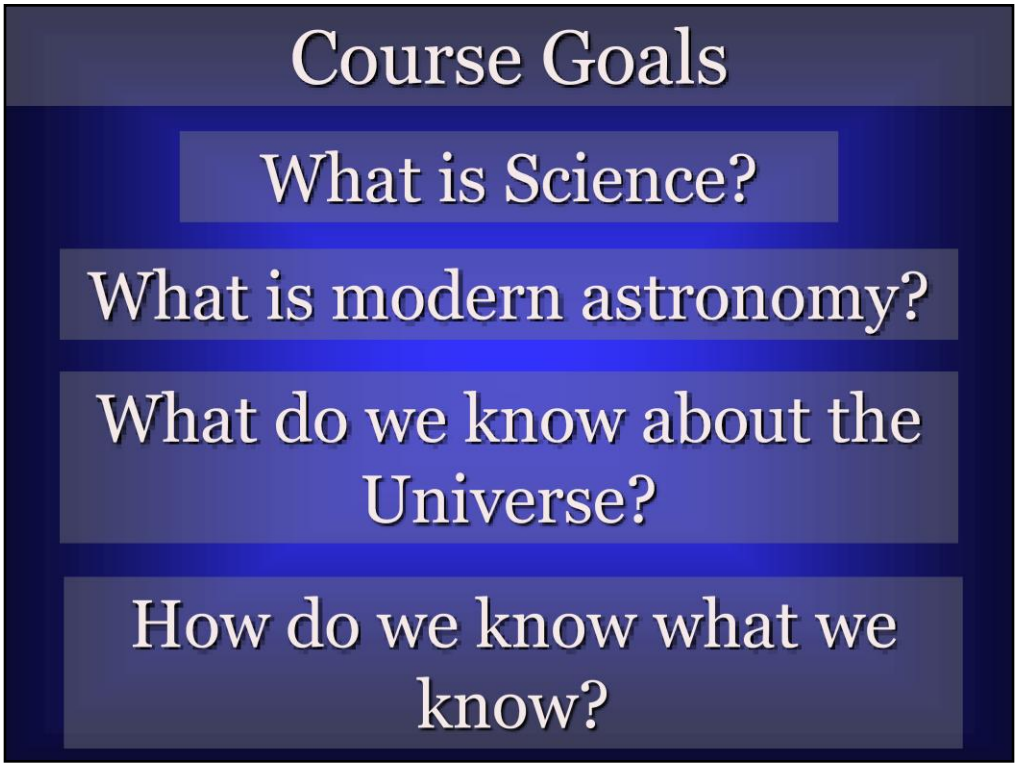


One of the main themes of this course is to answer the question:

What is Science?

At the same time, we want to answer the questions

"What ISN'T Science?"

What is science capable of?

What is it NOT capable of?

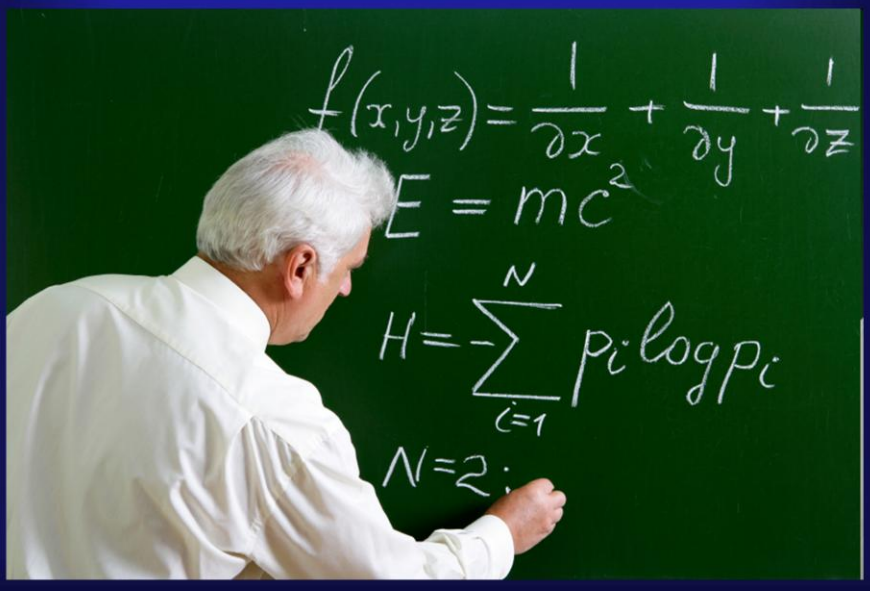
I want to paint a picture of what modern astronomy is.

How exactly do we study astronomy?

I also, of course, want to tell you what we know about the Universe.

But, I also want you to see HOW our modern view of the universe came into being.

Why Study Science?



Science gives us many things.

It improves the length and quality of our life by providing tools and technologies.
It allows us to understand our world, the universe, and our place in each.
It satisfies our innate curiosity and fulfills our spirit of exploration.

Why should we study science?

We need to learn to think rationally. We shouldn't just take what we're told by "authorities" as gospel. We should think critically about what we're told.

To think critically about messages from the scientific community, we must understand something about how the scientific community does business.

We are stewards of this planet and it's critical that we understand the consequences of our actions.

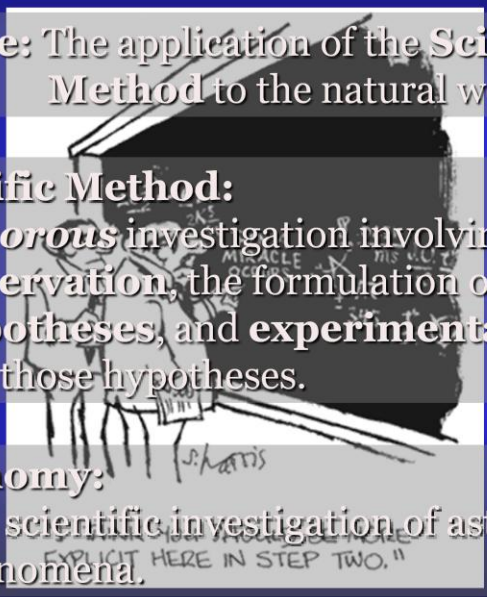
Science cannot progress without the support of an informed public.

Science

Science: The application of the **Scientific Method** to the natural world.

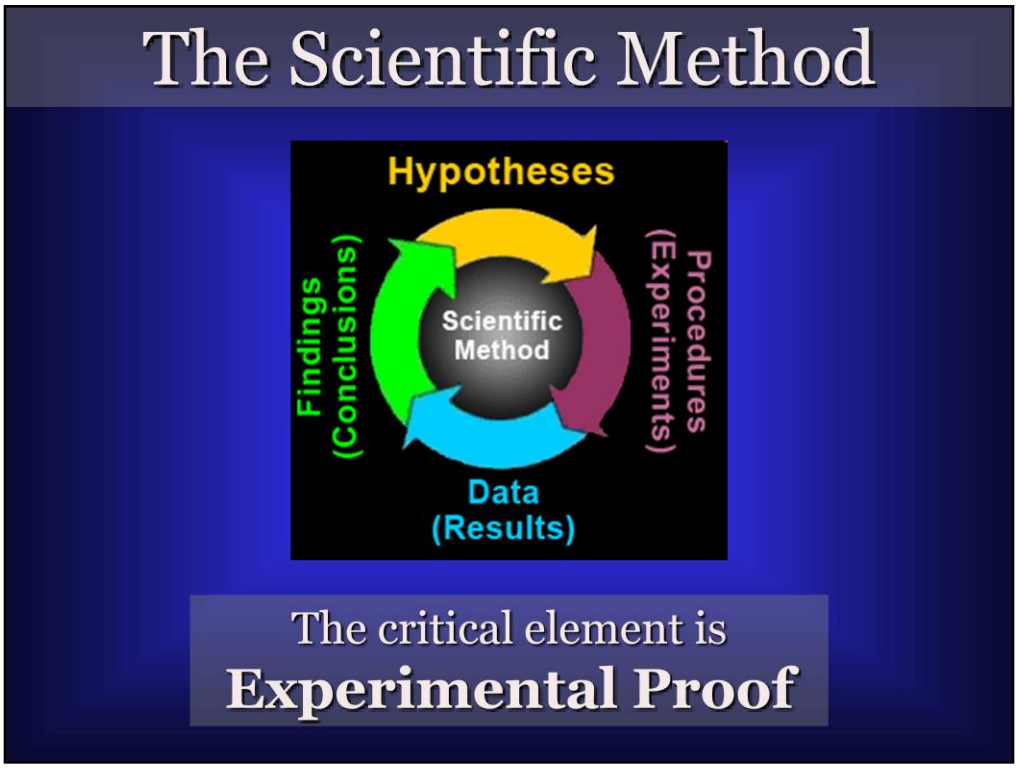
Scientific Method:
Rigorous investigation involving careful **observation**, the formulation of **hypotheses**, and **experimentation** to test those hypotheses.

Astronomy:
The scientific investigation of astronomical phenomena.



What exactly IS science?

These are some goofy definitions… But what is it REALLY?



This view of the scientific method is very tidy. It's not really how it works… but it's a nice metaphor

We observe a phenomena in nature and develop a hypothesis.

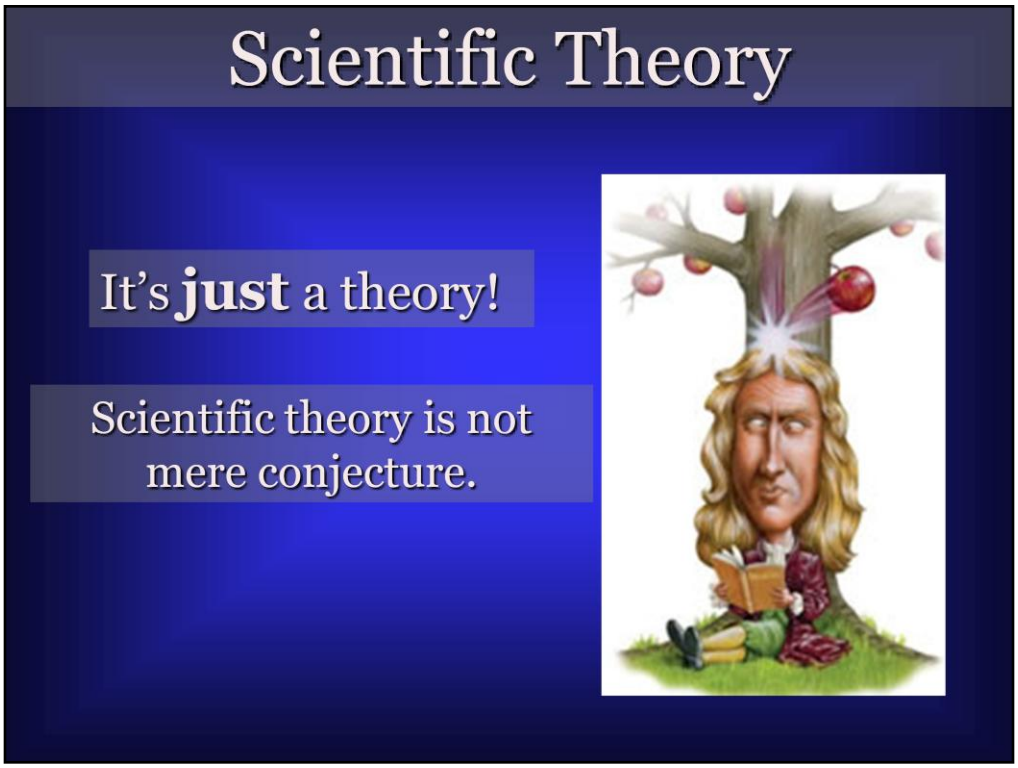
For this hypothesis to be valid, it must be TESTABLE and it MUST be based on observation.

When we perform the test, and nature tells us that our idea is wrong… It's wrong and we have to move on.

There is a difference between an incorrect hypothesis and an invalid hypothesis.

An invalid hypothesis is one that is not based on observation or provides no test.

An incorrect hypothesis is one that is valid, but fails the test.



The common use of the word Theory is not technically correct.

A scientific theory is not conjecture. A hypothesis is conjecture.

Once a hypothesis has the backing of experimental proof

it achieves the status of a Scientific Theory.

Scientific theories are not static. As scientists, we have to be prepared to modify or even

scrap old theories in light of new experimental evidence.

All of our theories are models of the natural world.

Their power of a theory lies in their ability to predict events in nature.

Missing Keys

Absent-Minded Professor Says Cure For Cancer 'Around Here Somewhere'

ENLARGE IMAGE

The cure, involving "smart enzymes" that locate and surround cancerous and anaplastic cells, effectively "suffocating" them, was the result of 28 years of research by the comically forgetful Huggins and his cancer research team at Johns Hopkins.

Sorting through a three-foot-high stack of papers in his living room, Huggins said of the revolutionary cure, "I remember sticking something in here a couple of days ago... I think it might have been the cure."

"Hundreds of thousands of experimental solutions over the last three decades were

Prof. Humbert E. Huggins has loc
over his office, but has not yet b
to find the cure for cancer. He b
the key to eradicating the disease
"in a big box under my dining roo

Group Discussion

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.

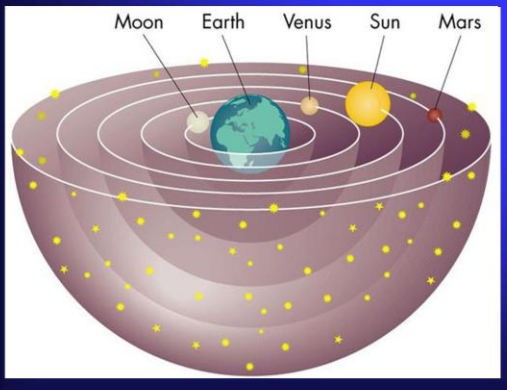
As far as we know, they were the first to do this.

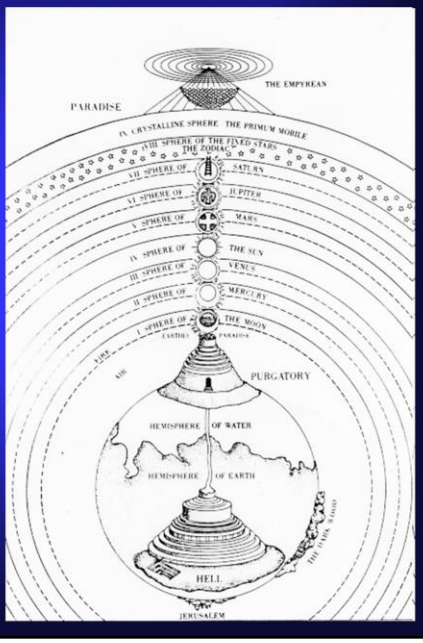
(The Western world calls Greece the birthplace of modern science)

The image on the right is the Antikythera device, a Greek astronomical computer.

A Hypothesis

The heavens are perfect and unchanging.
~Aristotle





Aristotle believe that one could sit around and simply THINK about nature and understand it.

He was not an astute observer of nature.

Aristotle believed that the heavens consisted of crystalline spheres and that the Earth was in the center.

Everything in the heavens was “perfect” and all celestial objects moved in perfect circles.

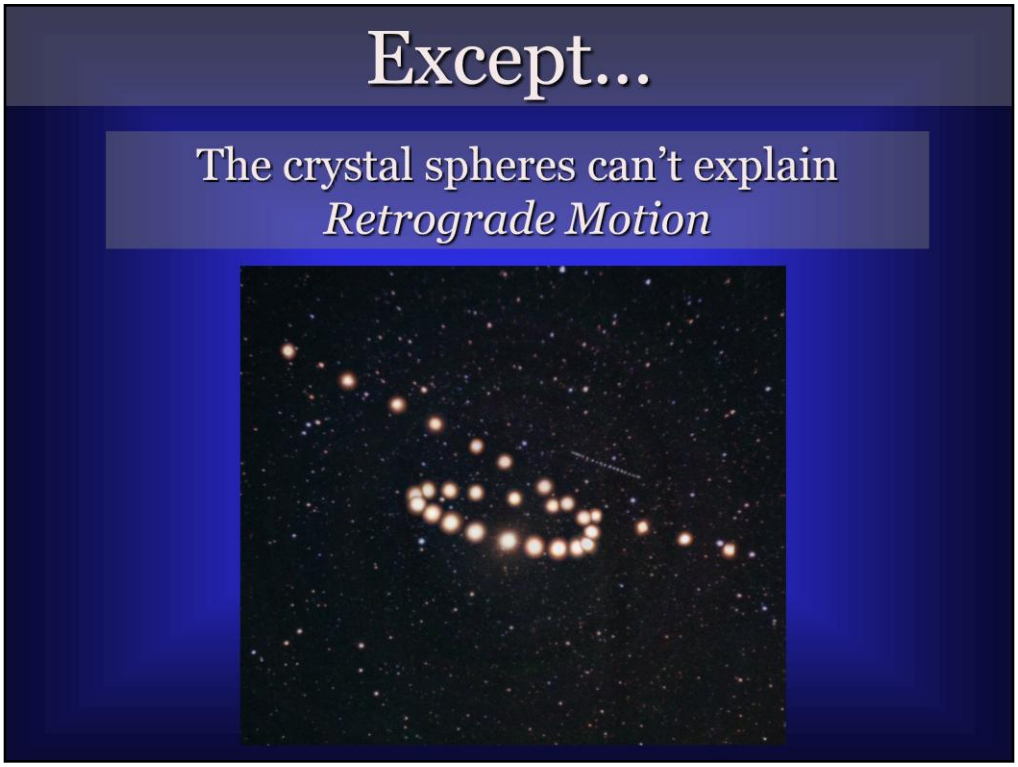
Celestial objects required no “impelling force” to keep them moving.

The Earth was the realm of the imperfect and impermanent.

The natural state of motion was a state of rest and everything on Earth decayed.

Aristotle’s crystalline sphere model was pretty lousy at making predictions of planetary positions.

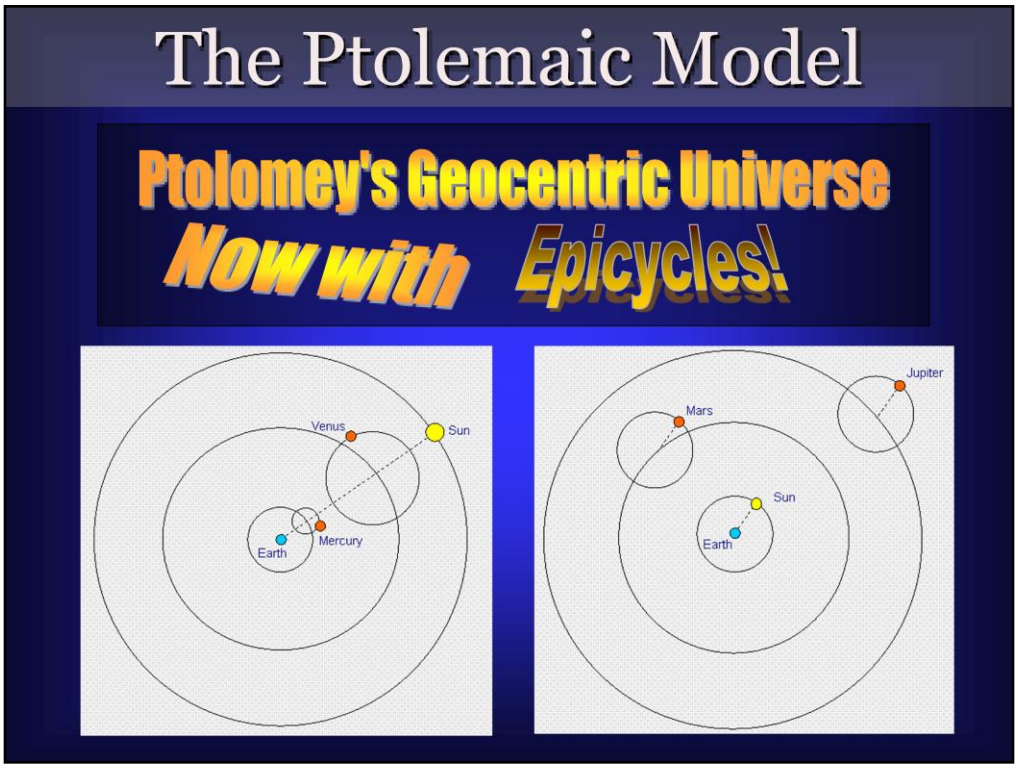
If he had actually LOOKED at the motions, he would have realized that his model was flawed.



This a compilation of photographs of the planet Mars.

Aristotle's spheres could not explain retrograde motion
the apparent "backwards" motion of a planet against the background stars.

And, it was pretty lousy at making accurate predictions.



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

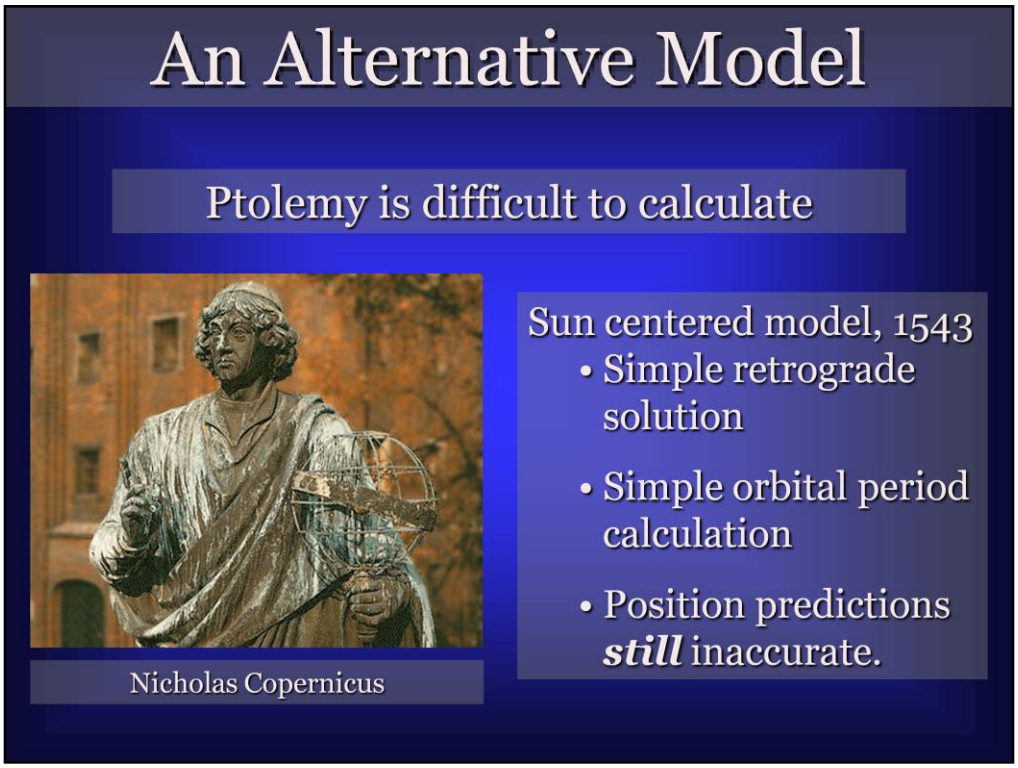
By adjusting the rates of each main orbit (deferent) and

each epicycle, the model could be tuned to fit observations

Ptolemy's model is REDICULOUSLY 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.



Scientists were tired of using the cumbersome Ptolemaic model to predict planetary positions.

Copernicus came up with a new model that put the Sun at the center and all of the planets

(including the Earth) in orbit around it. This type of model is called Helio-Centric. (sun-centered).

Because it still used circular orbits, it wasn't any more accurate than Ptolemy's model.

But, planetary positions were MUCH simpler to calculate.

And- it provided a simple and elegant explanation for the retrograde motion.

Nobody REALLY believed that the Sun was in the center though.

They used the Copernican model as a convenient calculator.

Because it had no greater predictive power, it was impossible to choose which model was correct.

New Observations

Tycho Brahe

Took 2 decades worth of naked eye planet observations

Accuracy to within 1 minute of arc

Tycho Brahe believe that Copernicus was correct and set out to prove it.

He made VERY careful observations of planetary positions over 20 years.
He died before he could complete his proof.

That task was left to his student…

ABCD

What was different about Ptolemy's model versus Aristotle's?

A. The spheres were glass, not crystal

B. The Sun is at the center, not the Earth.

C. He included EPICYCLES

D. Some of the crystal spheres went backwards.

Why wasn't Copericus's model immediately accepted as truth?

A. Don't be silly, it was a SMASH hit!

B. It's ***predictions*** were only as accurate as Ptolemy's but no better.

C. Copernicus was just not well liked.

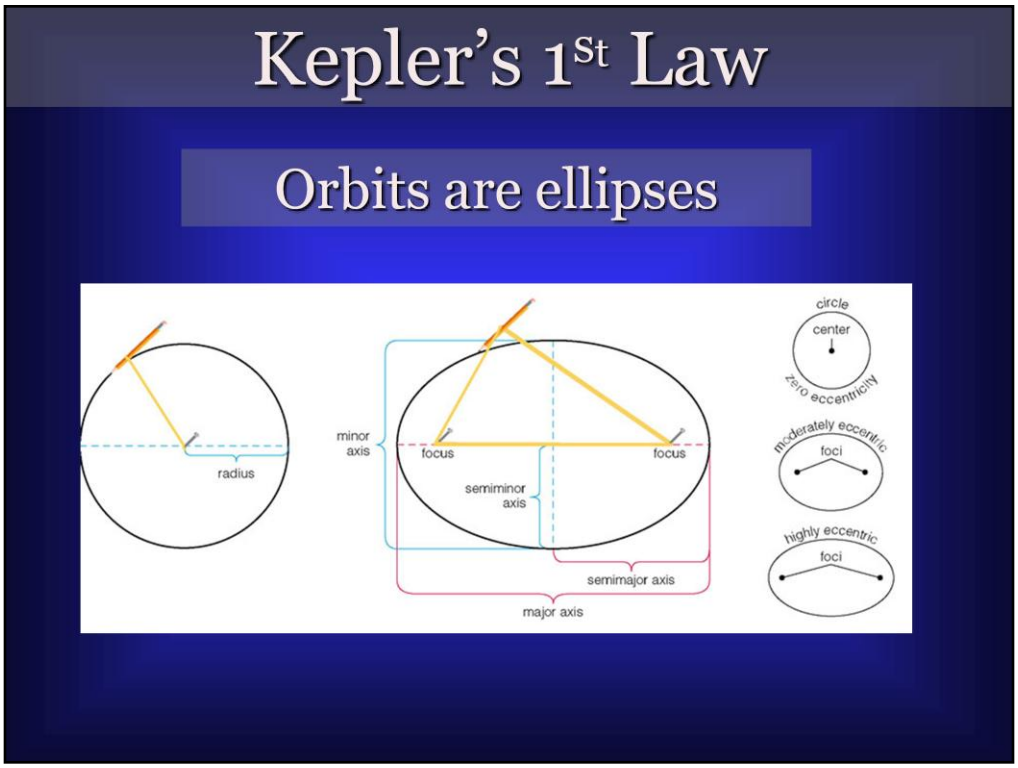
D. It's ***predictions*** were MUCH worse than Ptolemy's.

Theory

Johannes 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, studying Tycho's data, discovered three empirical relationships relating the numbers.

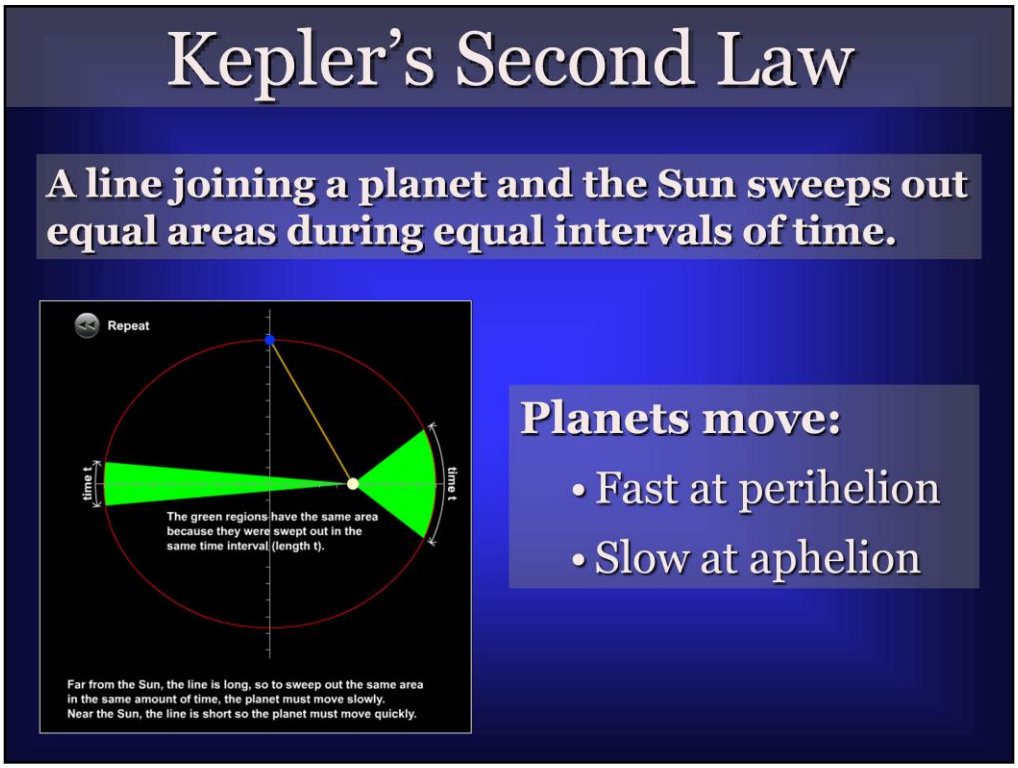


Orbits are not perfectly circular. They are elliptical.

An ellipse is sort of a squashed circle so that one axis is smaller than the other. The small axis is the minor axis, the large axis is the major axis.

A CIRCLE is a special kind of ellipse whose MAJOR and MINOR axis are equal.

An ellipse has two foci. At one focus is the gravitating body (The Sun, for example). At the other focus is empty space.

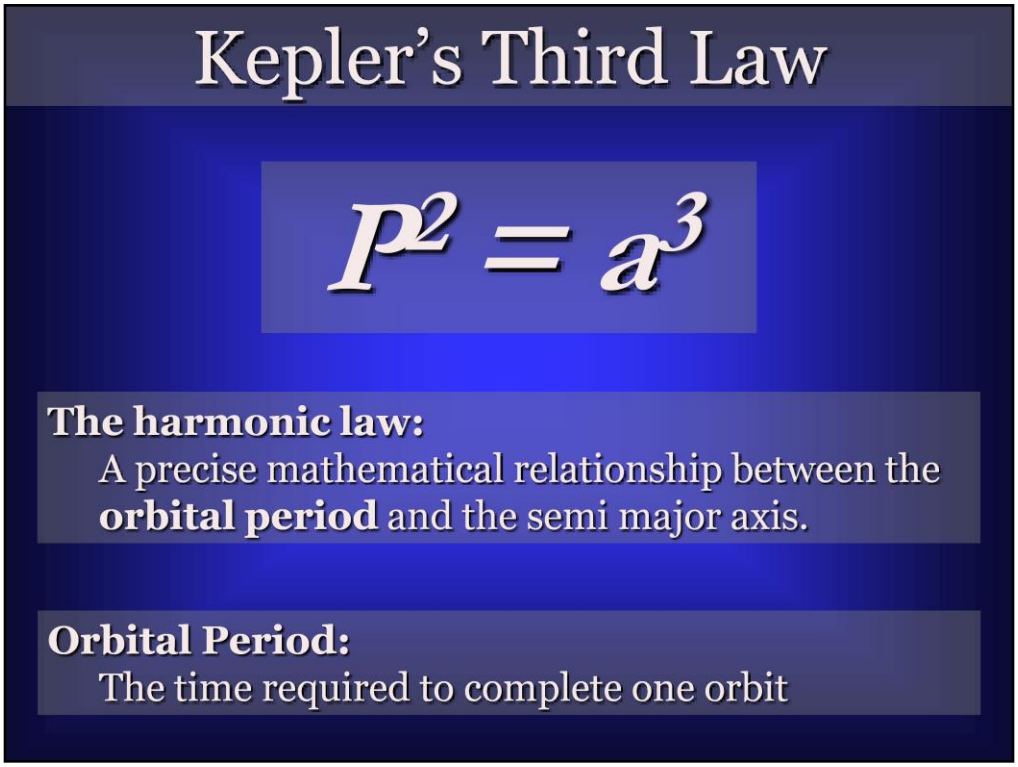


Kepler's Second Law says:

A line joining a planet and the Sun sweeps out equal areas during equal intervals of time

This implies that a planet in its orbit moves FAST at perihelion and SLOW at aphelion.

This is really just a restatement of the conservation of angular momentum.



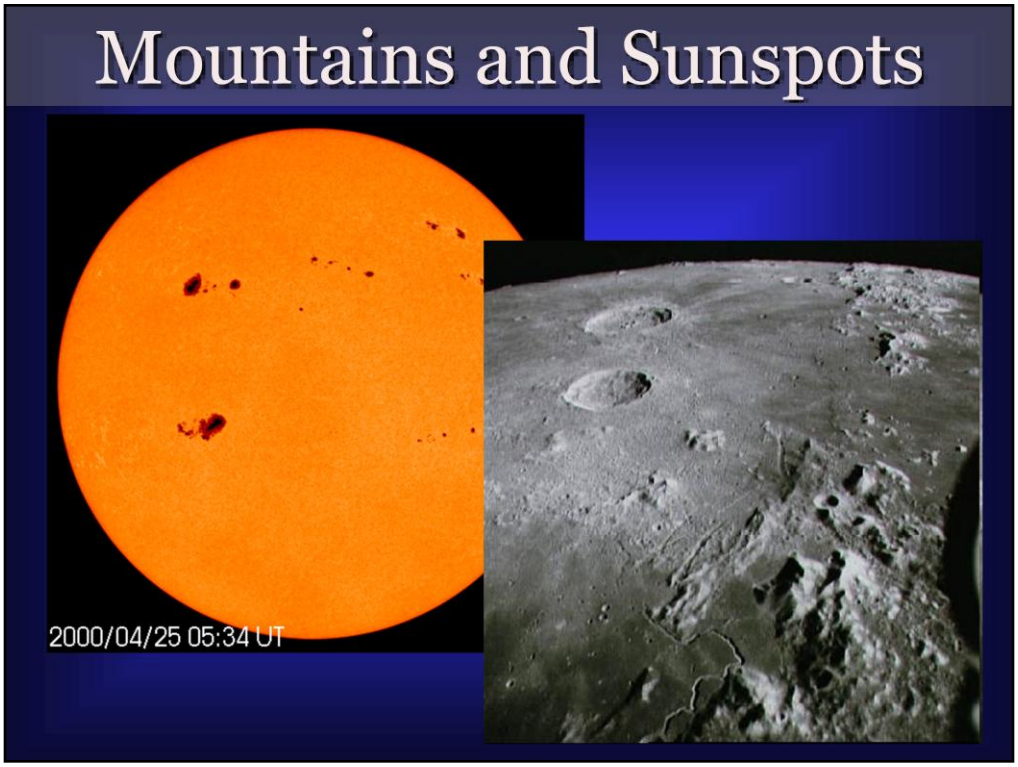
Kepler's Third Law says:

Planets far from the Sun have longer orbital periods than planets close to the Sun.

Pluto takes MUCH longer to go around the Sun than the Earth

The End of Geocentrism ... ?

Galileo in trouble.



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

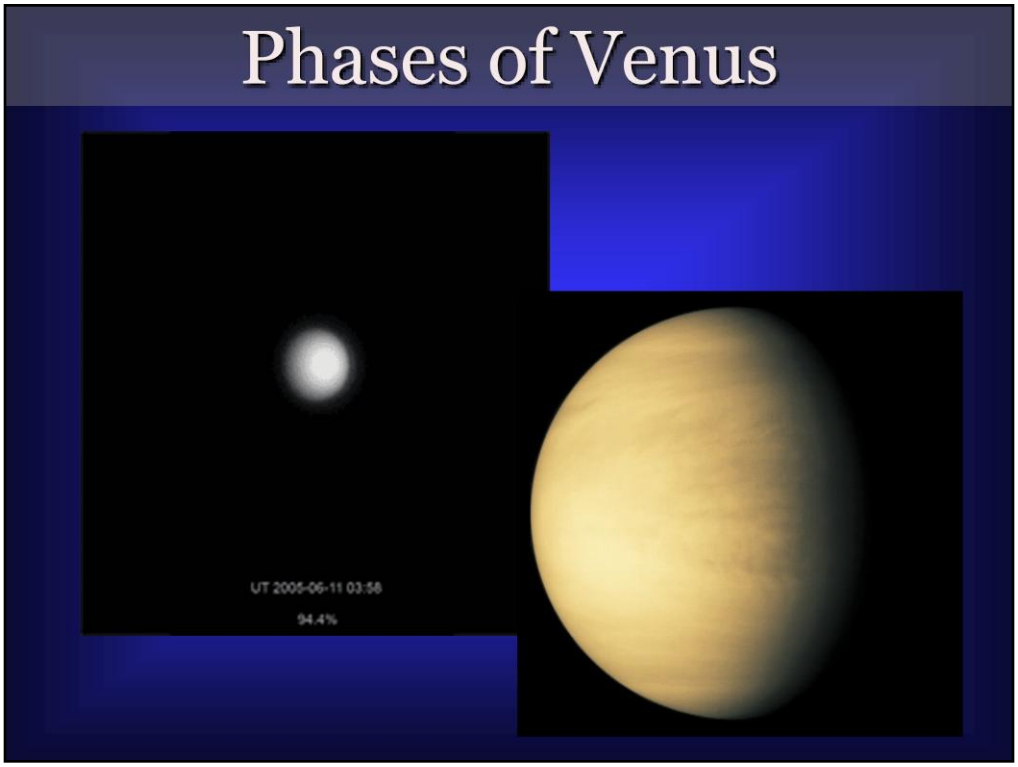
Aristotle says:

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

Galileo observes:

Jupiter has satellites of its own.

These “moons” are NOT going around the Earth



This is the KILLER observation.

Aristotle says:

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

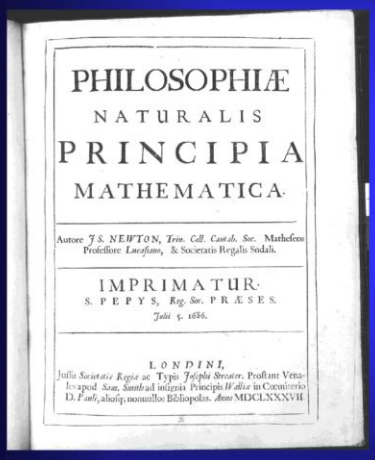
Galileo observes:

Venus and the Earth's Moon have 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.

The Rise of Modern Physics



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

Autore *Is. NEWTON, Trin. Coll. Cantab. Soc.* Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

IMPRIMATUR
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Justu Societatis Regiæ ac Typis *Josephi Streater.* Prostant Venales apud *Sam. Smith* ad insignia Principis *Walliæ* in Cœmiterio D. *Pauli*, aliosq; nonnullos Bibliopolas. *Anno* MDCLXXXVII.

Isaac Newton

- Three laws of motion
- Universal Gravitation
- The Calculus

Simple central principals from which all motion, either on Earth or in the heavens, can be derived.