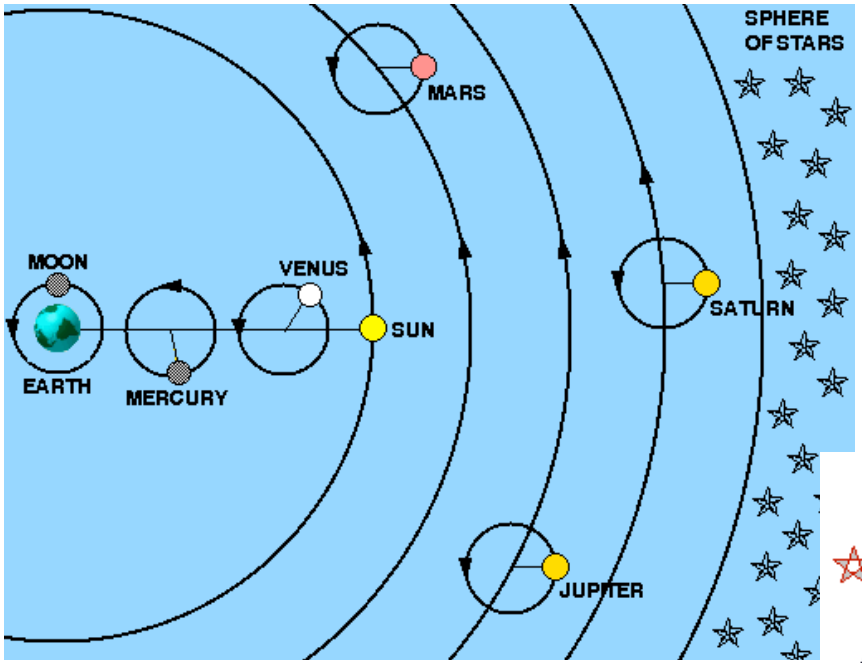
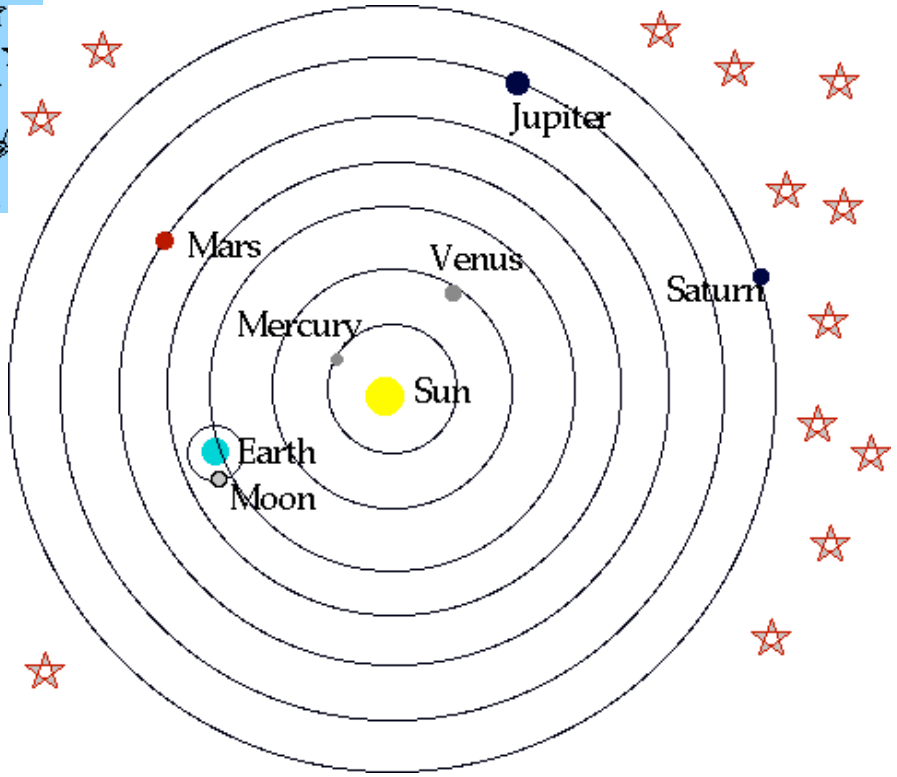
Competing Models

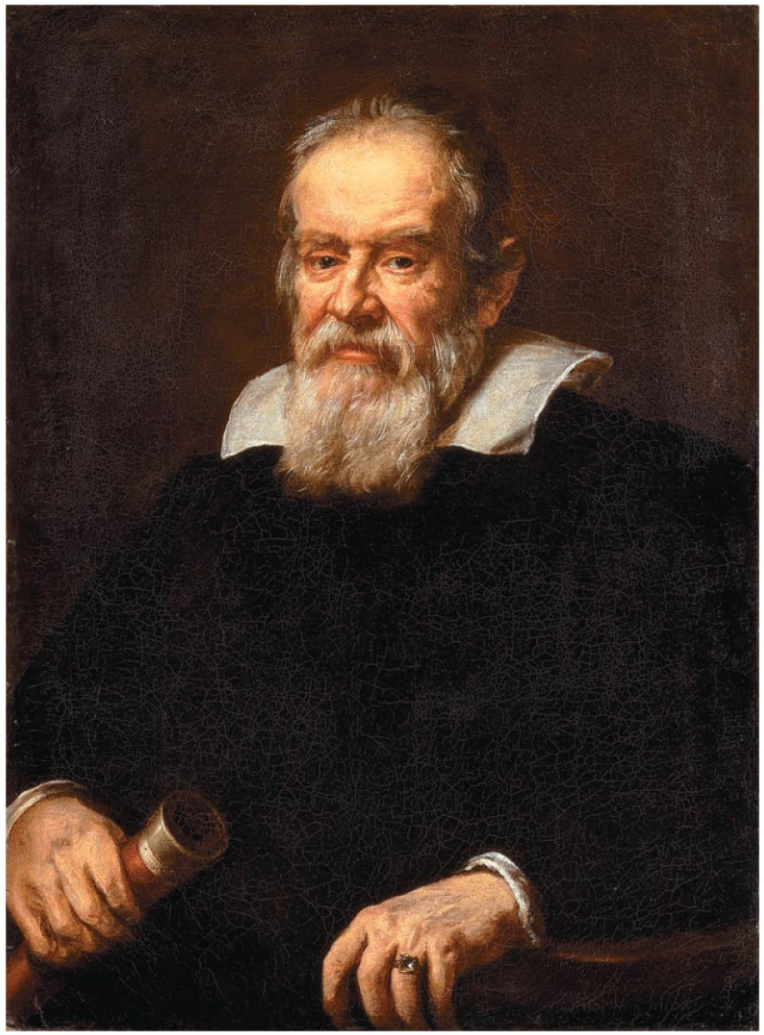


The Ptolemaic system (Geocentric)



The Copernican system (Heliocentric)

How did Galileo solidify the Copernican revolution?



Galileo (1564–1642)

Galileo overcame major objections to the 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 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 Earth as it moves.
  - 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):

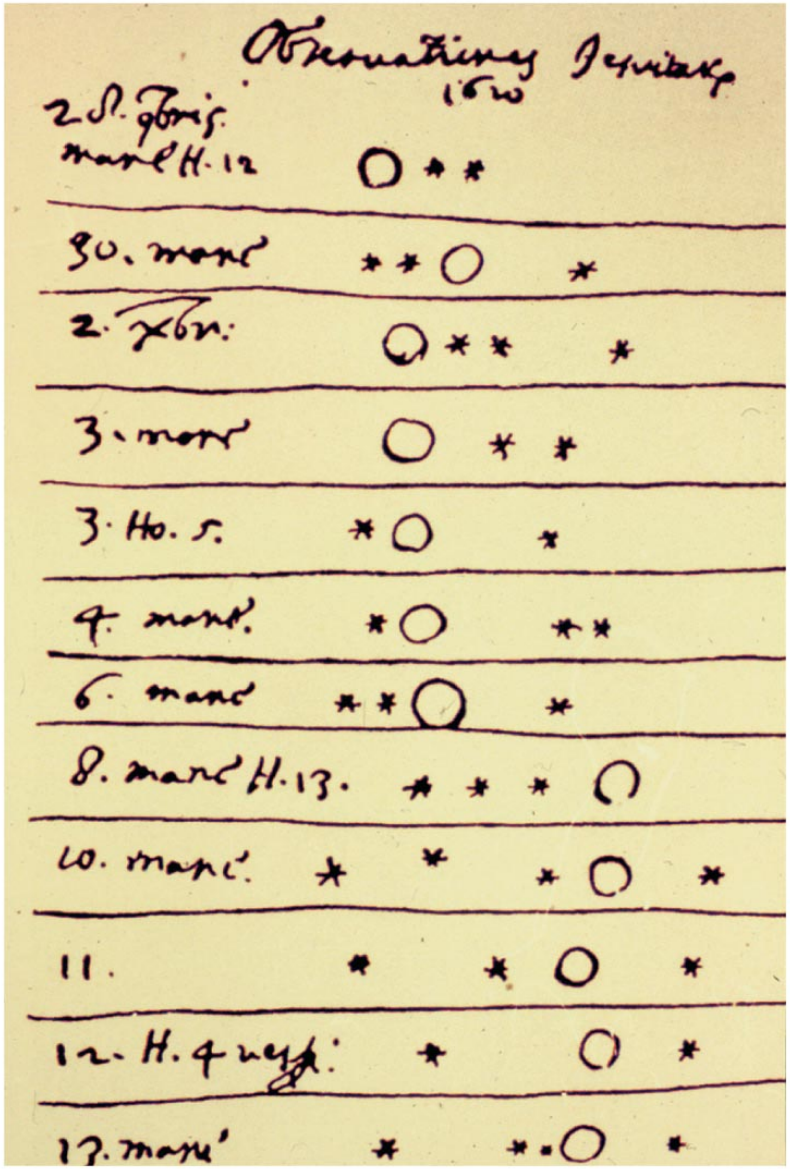
- Galileo was the first to turn the telescope to the night sky and record his observations.

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

Critical telescope observations!

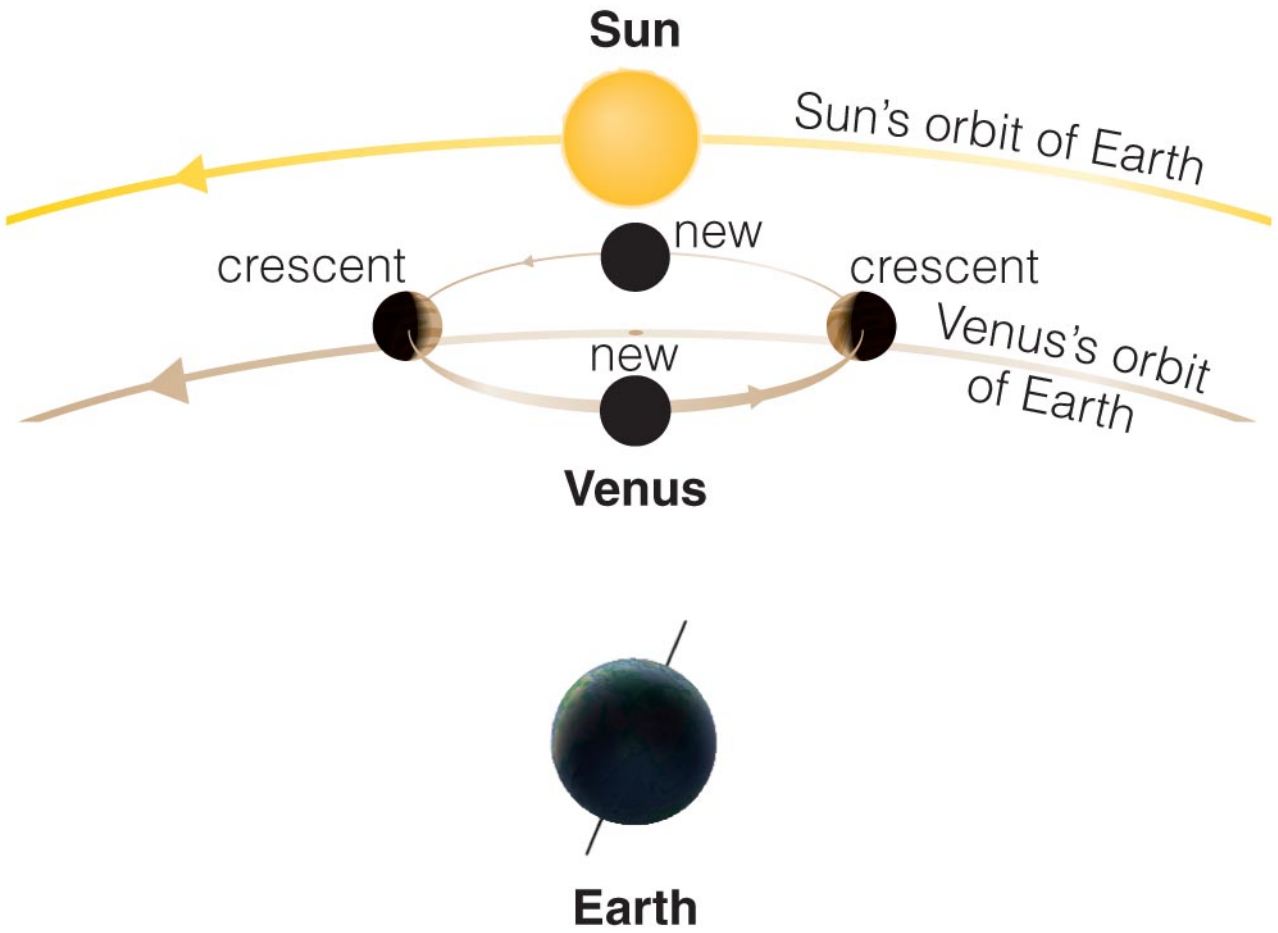


Galileo also saw four moons orbiting Jupiter, proving that not all objects orbit Earth.

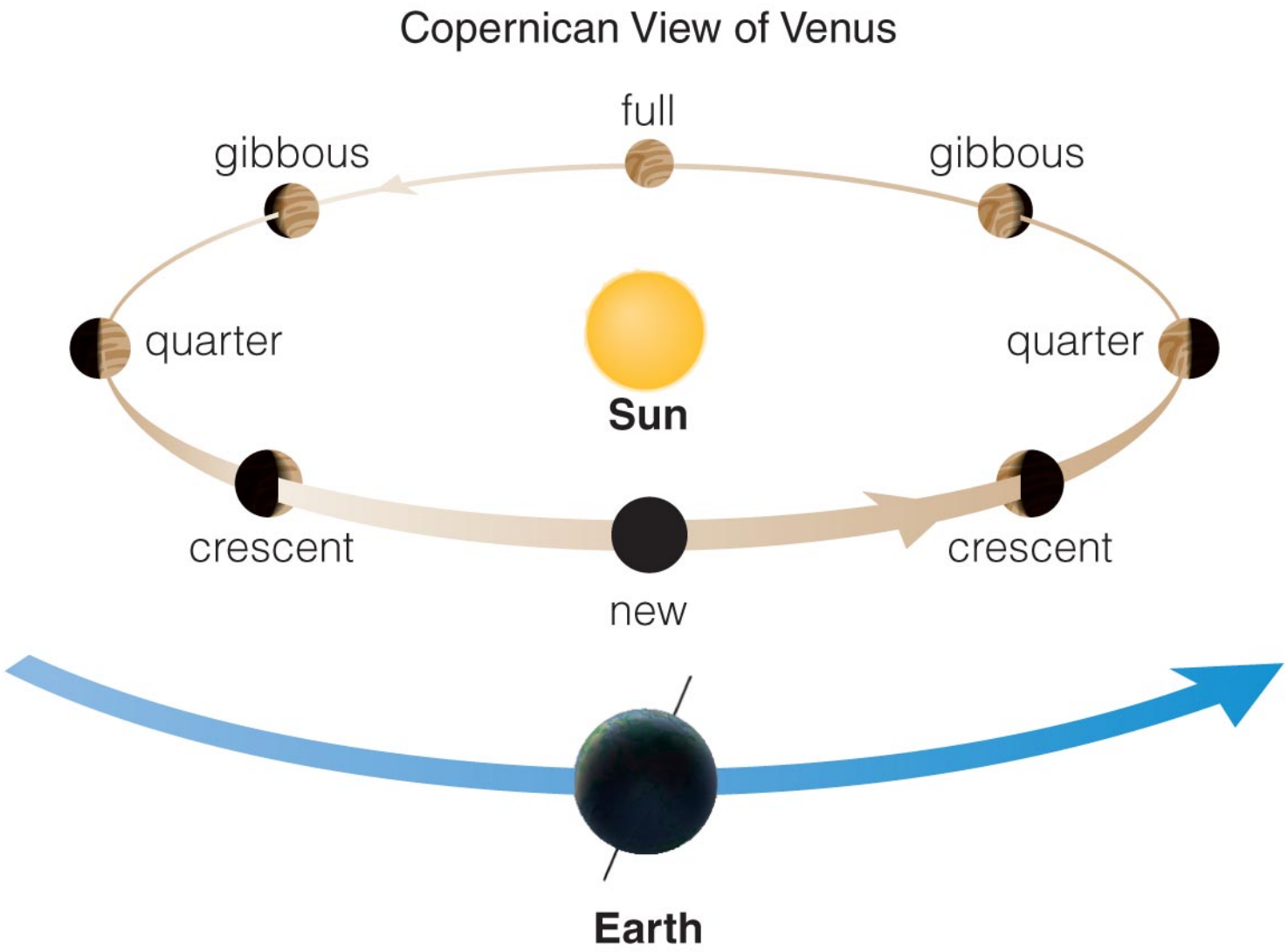
Critical telescope observations!

Galileo observed that Venus showed phases, which would be impossible under the Ptolmaic (geocentric) model.

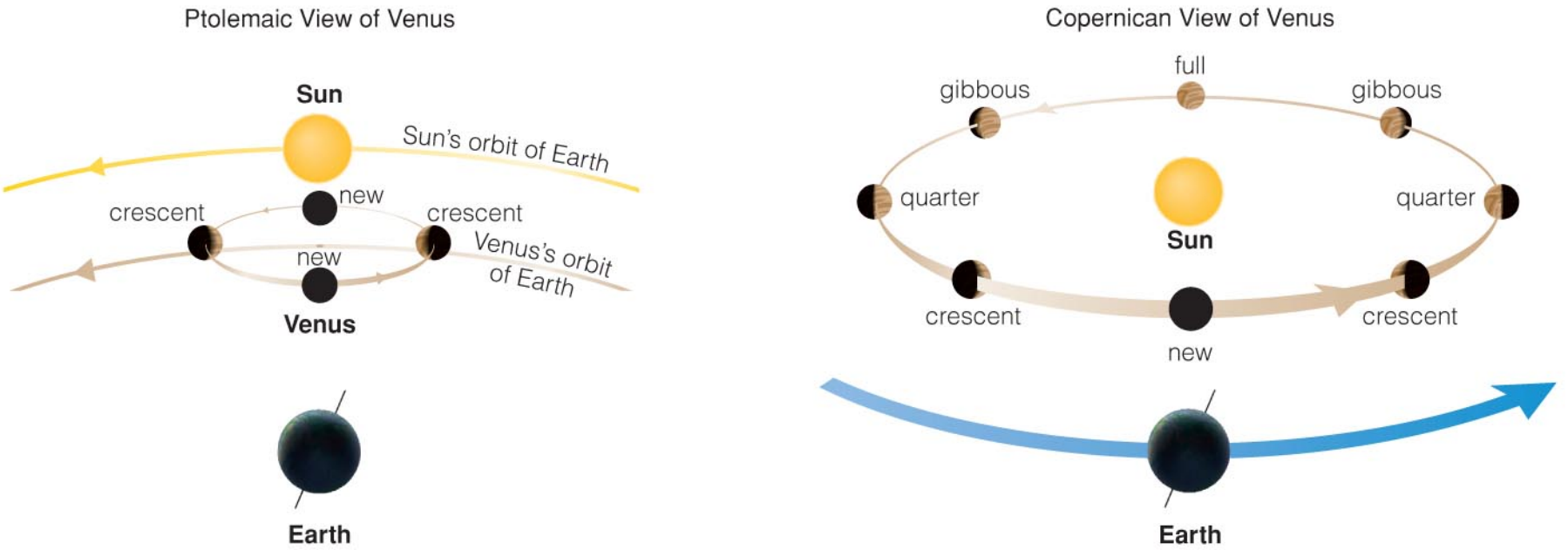
Ptolemaic View of Venus



a In the Ptolemaic system, Venus orbits Earth, moving around a smaller circle on its larger orbital circle; the center of the smaller circle lies on the Earth-Sun line. If this view were correct, Venus's phases would range only from new to crescent.



b In reality, Venus orbits the Sun, so from Earth we can see it in many different phases. This is just what Galileo observed, allowing him to prove that Venus orbits the Sun.



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Interactive Figure

- Galileo's observations of phases of Venus proved that it orbits the Sun and not Earth.

Fallout:

- The Catholic Church ordered Galileo to recant his claim that Earth orbits the Sun in 1633.
- 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.

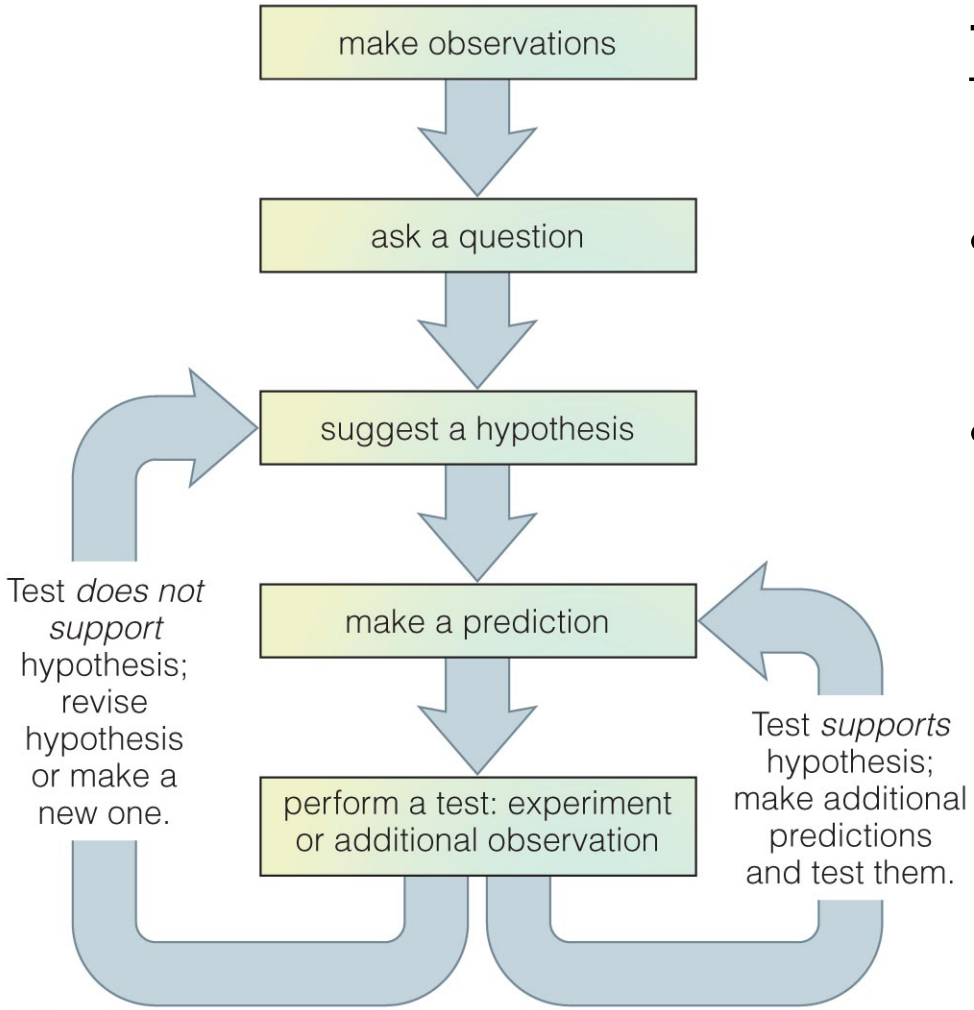
What have we learned?

- **How did Copernicus, Tycho and Kepler challenge the Earth-centered idea?**
  - Copernicus created a sun-centered model; Tycho provided the data needed to improve this model; Kepler found a model that fit Tycho's data.
- **What are Kepler's three laws of planetary motion?**
  - 1. The orbit of each planet is an ellipse with the Sun at one focus.
  - 2. As a planet moves around its orbit it sweeps out equal areas in equal times.
  - 3. More distant planets orbit the Sun at slower average speeds: $p^2 = a^3$.

What have we learned?

- **What was Galileo's role in solidifying the Copernican revolution?**
  - His experiments and observations overcame the remaining objections to the Sun-centered solar system model.

How can we distinguish science from non-science?



<u>The idealized scientific method</u>

- Based on proposing and testing hypotheses
- **hypothesis** = educated suggestion

- But science rarely proceeds in this idealized way. For example:
  - Sometimes we start by "just looking" then coming up with possible explanations.
  - Sometimes we follow our intuition rather than a particular line of evidence.

Hallmark of Science: #1

- Modern science seeks explanations for observed phenomena that rely solely on natural causes.

- (A scientific model cannot include divine intervention)

Hallmark of Science: #2

- Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.

(Simplicity = "Occam's razor")

Hallmark of Science: #3

- A scientific model must make testable predictions about natural phenomena that would force us to revise or abandon the model if the predictions do not agree with observations.

What is a scientific theory?

- The word theory has a different meaning in science than in everyday life.
- In science, a theory is NOT the same as a hypothesis, rather:
- A ***scientific theory*** must:
  - Explain a wide variety of observations with a few simple principles, AND
  - Must be supported by a large, compelling body of evidence.
  - Must NOT have failed any crucial test of its validity.