Philosophy of Science Survey

Week 8

PHIL 2160. Ohio University. Spring 2021.

Chapter 12: Astronomical Data: The Philosophical/Conceptual Facts

Facts (Review)

- Remember *facts* is our technical term. It will not mean what we mean in everyday contexts!
- Everyday (dictionary) meaning:

fact. n. “A thing that has actually happened or that is really true; the state of things as they are; reality; actuality; truth [fact as distinct from fancy]”

Facts (Review)

Our technical meaning:

A fact is a belief that is *deeply held and well-justified* in a given context of time.

Note:

1. A fact is a kind of belief.
2. A fact is not the same as truth (in our technical sense): A fact is a belief, so it can be true or false.

Empirical and Conceptual Facts (Review)

- An *empirical fact* – a belief that is deeply held and well-justified in a given context of time, and the primary source of justification is direct evidence.
- A *conceptual fact* – a belief that is deeply held and well-justified in a given context of time, and the primary source of justification is indirect evidence, that is, the belief's coherence with other beliefs of a worldview.

Empirical facts as data to be explained (Review)

- A scientific theory aims to predict and explain empirical facts.
- The role of conceptual facts is different.
- Conceptual facts ***constrain*** solutions to scientific problems.

Conceptual facts as constraints

- Conceptual facts ***constrain*** solutions to scientific problems.
  - Or: acceptable solutions to scientific problems must satisfy conceptual facts.
- We say "problems" to just mean "open questions."
  - That is, when we talk about problems in science, we are not talking about problems in the negative sense of the term (like when we say, "higher education has problems").
- Let's first try to understand the idea of constraint on solutions.

Conceptual facts as constraints

- In chess, your move is a proposed solution to the tactical problem at hand.
- Regardless of whether your move succeeds, it must satisfy the rules of the game.
- That is, the rules ***constrain*** your moves.

Conceptual facts as constraints

- Scientists solve problems (of their day) by proposing solutions.
  - Solutions could be an individual hypothesis or a more elaborate theory.
- But in a given time, not all solutions are equally acceptable.
- Rather, proposed solutions have to satisfy conceptual facts.
- That is, conceptual facts ***constrain*** solutions to scientific problems.

Conceptual Facts in the Aristotelian Astronomy

- For Aristotelian astronomers, a major scientific problem was to predict and explain the motion of planets (e.g., retrograde motion) and stars.
- Any acceptable solution to this problem had to satisfy two basic constraints (conceptual facts).

1. The perfect circle constraint: celestial bodies move in perfect circles.
2. The uniform motion constraint: celestial bodies move uniformly (i.e., at constant speeds).

Conceptual Facts in the Aristotelian Astronomy

- In other words, in the Aristotelian astronomy, any acceptable solution to astronomical problems had to invoke only ***uniform circular motion***.
- This constraint on astronomical theorizing was respected by all major theoreticians, such as Ptolemy, Copernicus, and Brahe.
    - We'll read their theories in the next chapters.
- In the 17th century, Kepler proposed a solution invoking elliptical orbits.
    - Note that Kepler's move was like a chess move that violated the rules! The acceptance of this solution required changes in the constraints themselves.

Conceptual Facts in the Aristotelian Astronomy

- In the Aristotelian astronomy, any acceptable solution to astronomical problems had to invoke only ***uniform circular motion***.
- In addition, acceptable solutions had to:
  - Cohere with other beliefs in the Aristotelian worldview.
  - Predict and explain the empirical facts.
- Problem solving in science is like finding (empirically or conceptually) a puzzle piece that fits into a hole in the jigsaw puzzle you have built so far.
  - This picture applies to contemporary science too.

A Scientific Problem in the Aristotelian Astronomy

- This is just one example of many scientific problems in the Aristotelian astronomy. We'll call this problem

The problem of continuous motion

Why do celestial bodies move continuously?

- **The rules.** An acceptable solution must (i) invoke only uniform circular motions, (ii) predict and explain observed motions of celestial bodies, and (iii) cohere with other, especially core, beliefs of the Aristotelian worldview.

A Scientific Problem in the Aristotelian Astronomy

- Recall that science does not aim to solve every problem you can think of (review Week 7).
- In other words, there needs to be good motivations for scientific problems.
- What, then, was the motivation for the problem of continuous motion?

A Scientific Problem in the Aristotelian Astronomy

- The main motivation was the discrepancy between the observed motion of celestial bodies and the principle of motion Aristotelians held:

Pre-1600s principle of motion (DeWitt):

An object in motion will come to a halt, unless something keeps it moving.

- The motion of celestial bodies appears continuous, in violation of this core belief of the Aristotelian worldview. So their continuous motion needed to be explained.

A Scientific Problem in the Aristotelian Astronomy

The problem of continuous motion

Why do celestial bodies move continuously?

- **The rules.** An acceptable solution must (i) invoke only uniform circular motions, (ii) predict and explain observed motions of celestial bodies, and (iii) cohere with other, especially core, beliefs of the Aristotelian worldview.
  - *The pre-1600s principle of motion* is part of (iii). That is, it’s not acceptable to modify this principle itself (which would be like changing the rules of chess to make a move).

A Scientific Problem in the Aristotelian Astronomy

The problem of continuous motion

Why do celestial bodies move continuously?

- *The pre-1600s principle of motion* suggests that celestial bodies move continuously because something keeps them moving.
- But this something cannot itself be in motion, because if it were, then there would have to be another thing that keeps it moving.
- Aristotle called this something that keeps celestial bodies moving *unmoved mover*.

A Scientific Problem in the Aristotelian Astronomy

The problem of continuous motion

Why do celestial bodies move continuously?

- The solution so far is:

Because the unmoved mover keeps celestial bodies moving.

- Of course, this solution raises other questions, such as, What is the nature of the unmoved mover?

A Scientific Problem in the Aristotelian Astronomy

- What is the nature of the unmoved mover?
- Aristotle's reasoning is that *an object of desire* is the only thing that is not itself in motion but which can cause motion.
  - DeWitt's illustration is our moving towards someone we want to be with.
- Another example is your home or natural place (think of any favorite place). Your home is not moving, but it makes you move by being an object of your desire.
- Notice that this explanation of your motion is related to Aristotelian teleology. (see next)

A Scientific Problem in the Aristotelian Astronomy

- Compare:

a. Your home, which is not moving, makes you move by being an object of your desire.

b. You are going home because you want to be there.

- (b) is a standard example of teleological explanations (review Week 6).
- (a) is a restatement of (b).

A Scientific Problem in the Aristotelian Astronomy

- Recall Aristotelian teleology applied to *non-living, non-artefactual things* as well (review Week 6).
- For these things, an object of desire is their natural place, pattern, etc.
  - Example: the natural place of the earth element is the center of the universe.
- And *desire* in these cases means natural tendency.
  - To say that the earth element's *desire* is to be at the center of the universe is to say that the earth element has *a natural tendency* to be at the center of the universe.

A Scientific Problem in the Aristotelian Astronomy

- DeWitt notes that the Greek concept of desire as applied to inanimate objects is *unconscious desire.*
- Today we don't have this concept, but as DeWitt suggests, we can understand unconscious desire as natural tendency.
  - E.g., water has a natural tendency to move towards lower elevations. This tendency is what is referred to by the Greek concept of "unconscious desire" of water.
- This talk of natural tendency *is* familiar to us in cases of living things.
  - "Cats tend to meow." Here we mean natural tendency.

A Scientific Problem in the Aristotelian Astronomy

The problem of continuous motion

Why do celestial bodies move continuously?

- The solution so far:

*Because the unmoved mover keeps celestial bodies moving **by being the object of desire.***

- Note how this solution satisfies the constraints.
- But of course this raises further questions, such as, What is the desire (natural tendency) of celestial bodies?

A Scientific Problem in the Aristotelian Astronomy

- What is the desire (natural tendency) of celestial bodies?
- Aristotle's reasoning is that celestial bodies must desire (have a natural tendency toward) perfection.
- This is because celestial bodies exist in the superlunar region, which is the region of perfection.
  - The idea that the heavens (the sky, not anything religious) are a place of perfection is a very common and traditional view (ancient even in Aristotle's time).
- So the unmoved mover is the perfection that celestial bodies desire (naturally tend toward).

A Scientific Problem in the Aristotelian Astronomy

The problem of continuous motion

Why do celestial bodies move continuously?

- The solution so far:

Because the unmoved mover keeps celestial bodies moving ***by being the perfection that celestial bodies desire.***

- Note how this solution satisfies the constraint (conceptual fact) of ***uniform circular motion***, because that was regarded as a kind of perfect motion.

A Scientific Problem in the Aristotelian Astronomy

- You might notice that the solution so far can answer a more detailed version of the problem of continuous motion.

The problem of continuous motion (detailed version)

Why do celestial bodies move continuously in perfect circles?

- The solution so far:

Because the unmoved mover keeps celestial bodies moving by being the perfection that celestial bodies desire, and perfect circles are a kind of perfection.

A Scientific Problem in the Aristotelian Astronomy

- As you expect, this solution raises further questions, such as, Why do *only* celestial bodies desire perfection? That is, why is the natural tendency of celestial bodies perfection, when nothing else tends toward perfection?
- Note that an acceptable answer to this question must cohere with other beliefs of the Aristotelian worldview.

A Scientific Problem in the Aristotelian Astronomy

- Aristotle’s answer is rather simple: *Because celestial bodies are made of an element that only exists in the superlunar region*.
  - The name of this element is ether.
- Aristotle’s answer here is quite reasonable.
- We want to explain why only celestial bodies do things that nothing else on Earth does. The answer is because they are made of a difficult substance.
  - Instead, if we said that celestial bodies are made of the earth element, we would have to explain why only some earth elements behave so differently from every other earth element.

A Scientific Problem in the Aristotelian Astronomy

The problem of continuous motion

Why do celestial bodies move continuously?

- The solution so far:

Because the unmoved mover keeps celestial bodies moving by being the perfection that celestial bodies desire, and perfect circles are a kind of perfection. Moreover, only celestial bodies desire perfection because they are the only objects made of ether.

A Scientific Problem in the Aristotelian Astronomy

- This solution satisfies all the rules.
- **The rules.** An acceptable solution must (i) invoke only uniform circular motions, (ii) predict and explain observed motions of celestial bodies, and (iii) cohere with other, especially core, beliefs of the Aristotelian worldview.
  - *The pre-1600s principle of motion* is part of (iii). That is, it's not acceptable to modify this principle itself (which would be like changing the rules of chess to make a move).

A Scientific Problem in the Aristotelian Astronomy

- As you might expect, the Aristotelian solution raises further questions.
- So far we said that the unmoved mover is the perfection that celestial bodies desire.
- What kind of perfection is the unmoved mover?

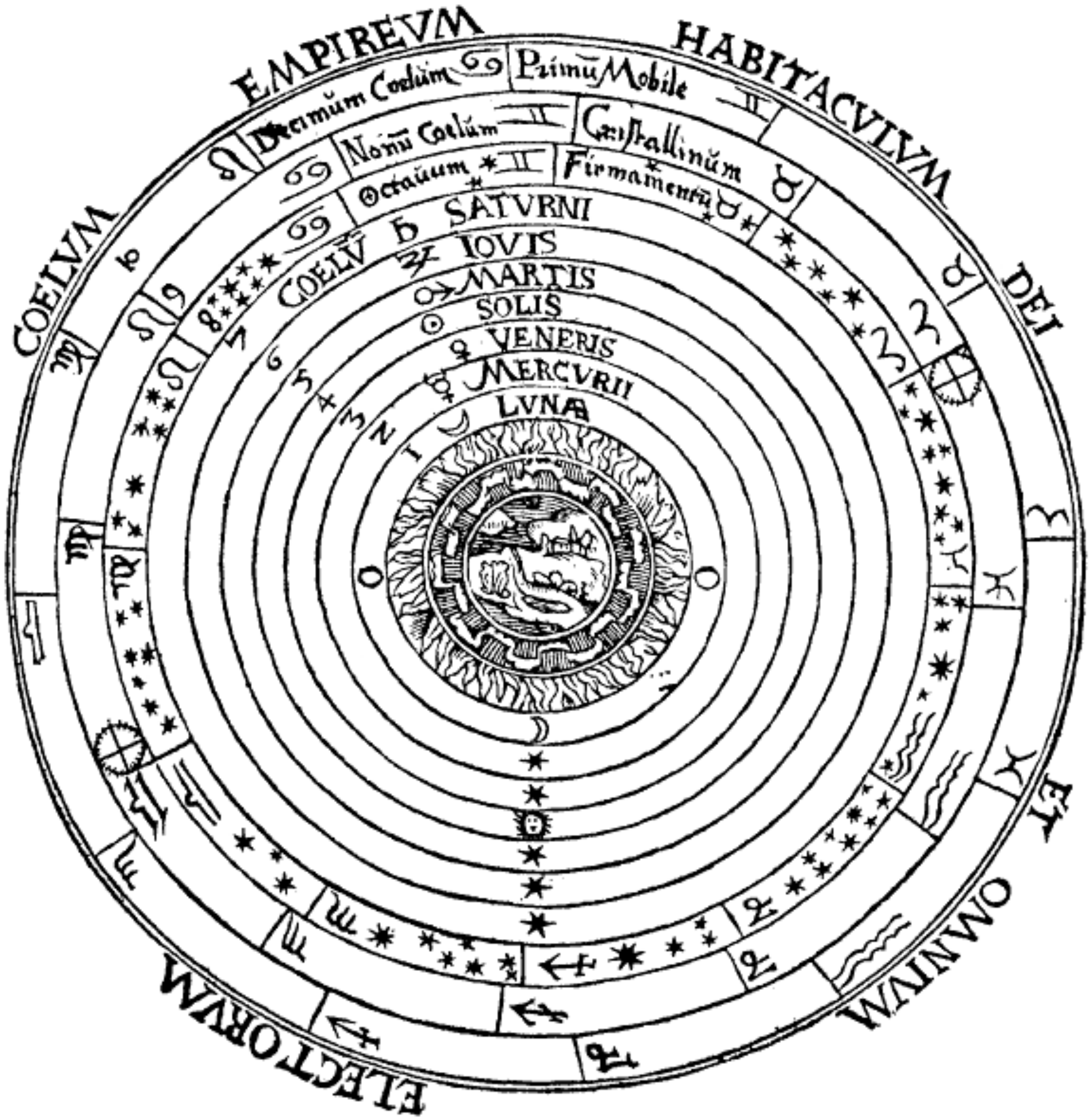
A Scientific Problem in the Aristotelian Astronomy

- As we said, for Aristotle, the superlunar region is a place of perfection.
- Celestial bodies desire perfection even though they already exist in a place of perfection.
- So the perfection of the unmoved mover that celestial bodies desire must be the *absolute perfection* or the perfection of all perfection.
- Aristotle called such absolute perfection godlike.

A Scientific Problem in the Aristotelian Astronomy

- But by “god” or “godlike” Aristotle didn’t mean anything religious we might think of.
- In fact, as we saw, Aristotle’s “god” (absolute perfection) was simply introduced as necessary to explain why celestial bodies move continuously. It did not play any other role.
- Later, when Christians appropriated the Aristotelian worldview, Aristotle’s ideas about the unmoved mover were also Christianized.

Schema huius præmissæ diuisionis Sphærarum.



Peter Apian’s representation of the universe from his *Cosmographia* (1524) (https://en.wikipedia.org/wiki/Petrus_Apianus)

Note the Christianization of the Aristotelian universe: the outermost part is the empire of God.

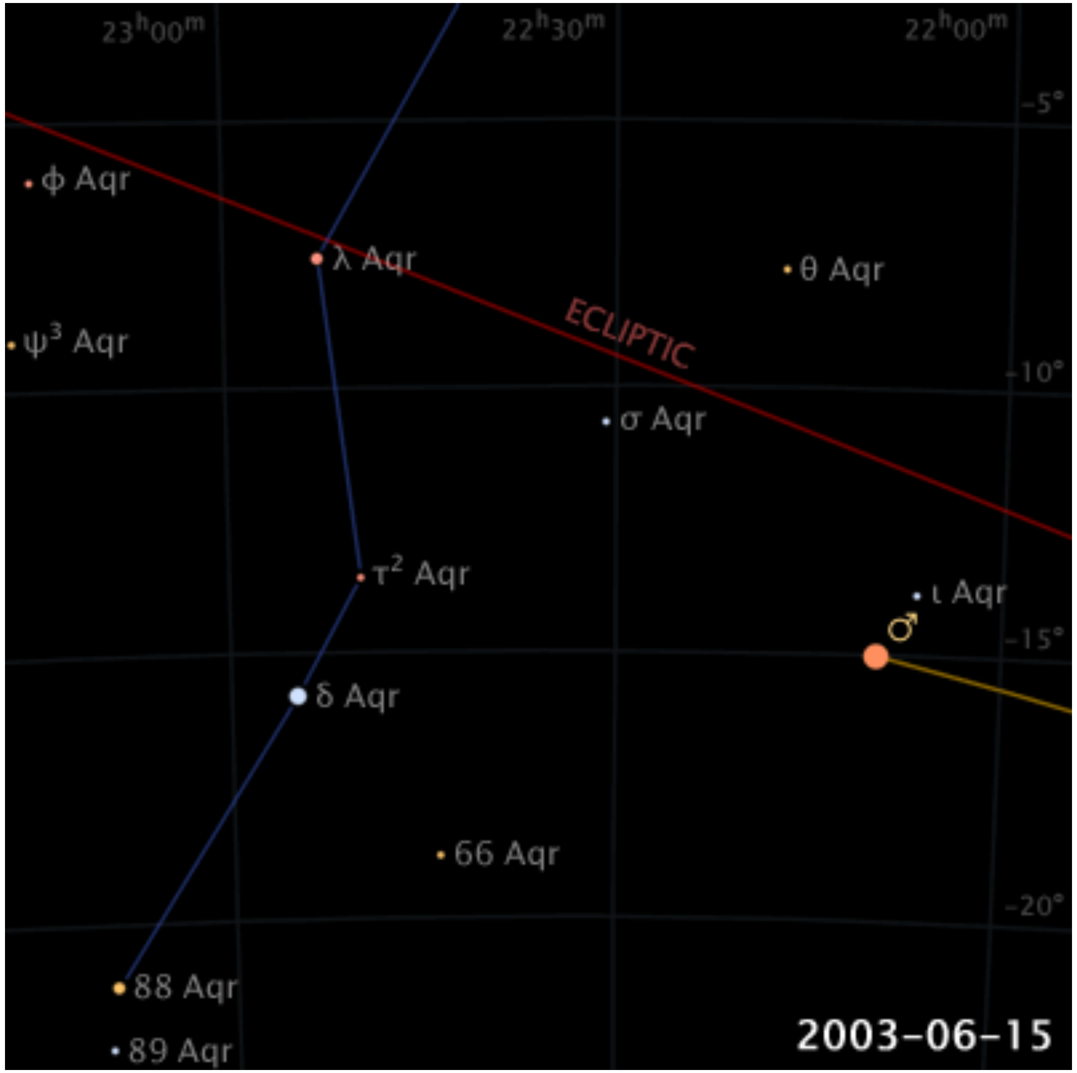
Chapter 13: The Ptolemaic System

The Problem of the Planets

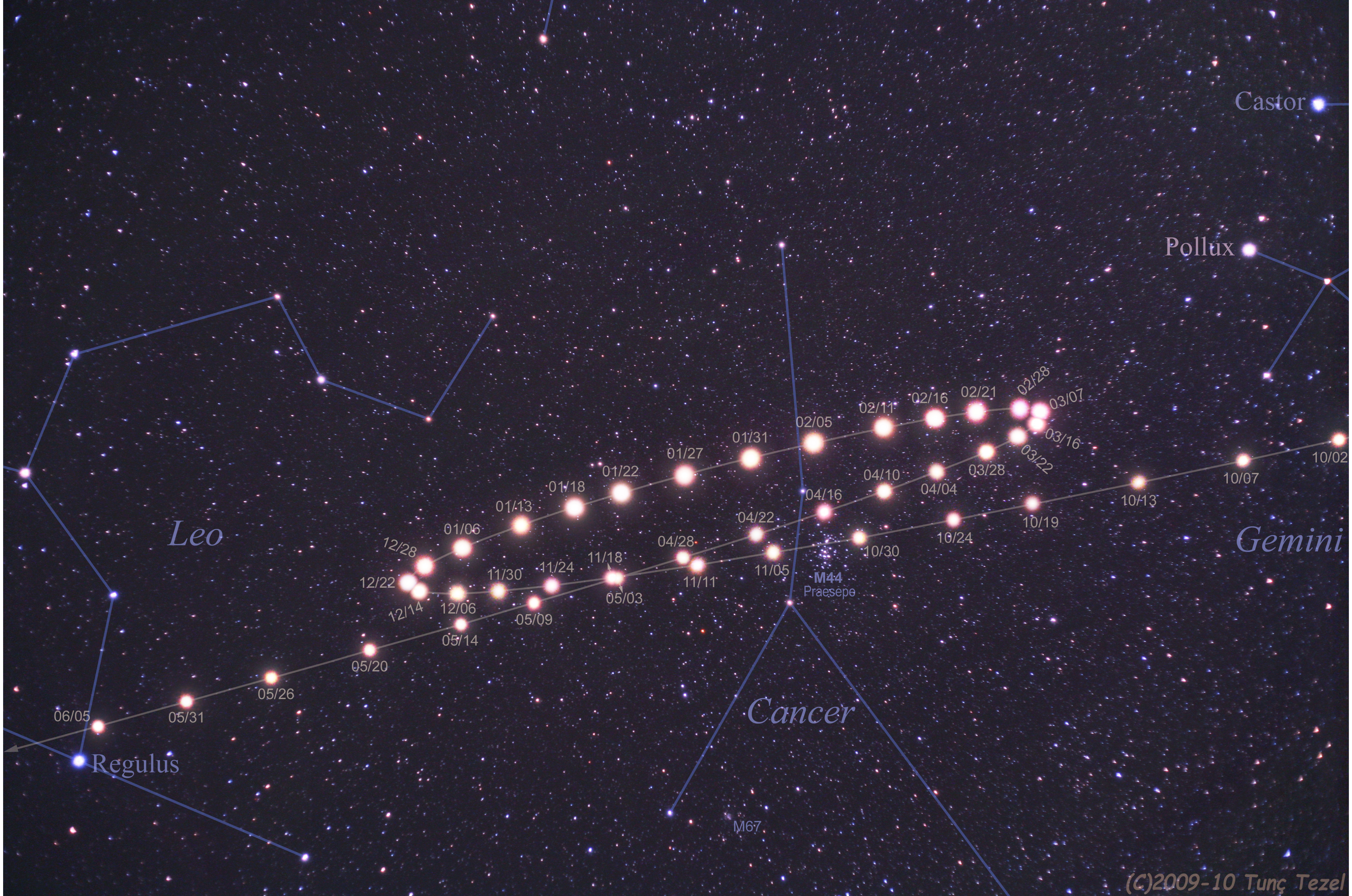
- Recall “planets” just mean wandering dots of light in the sky.
- There are two main empirical facts about the planets.

1. Planets drift with respect to the fixed stars.
2. Planets exhibit retrograde motion.

- Recall that “retrograde motion” refers only to *observed motion of the dots in the sky*. We are not talking about whether celestial bodies really move in this way.



Retrograde motion of Mars as seen from Earth (2003)


Castor
Pollux
Leo
Gemini
Cancer
Regulus
M44
Praesepe
M67
10/02
10/07
10/13
10/19
10/24
10/30
11/05
11/11
11/18
11/24
11/30
12/06
12/14
12/22
12/28
01/06
01/13
01/18
01/22
01/27
01/31
02/05
02/11
02/16
02/21
02/28
03/07
03/16
03/22
03/28
04/04
04/10
04/16
04/22
04/28
05/03
05/09
05/14
05/20
05/26
05/31
06/05
(C)2009-10 Tunç Tezel

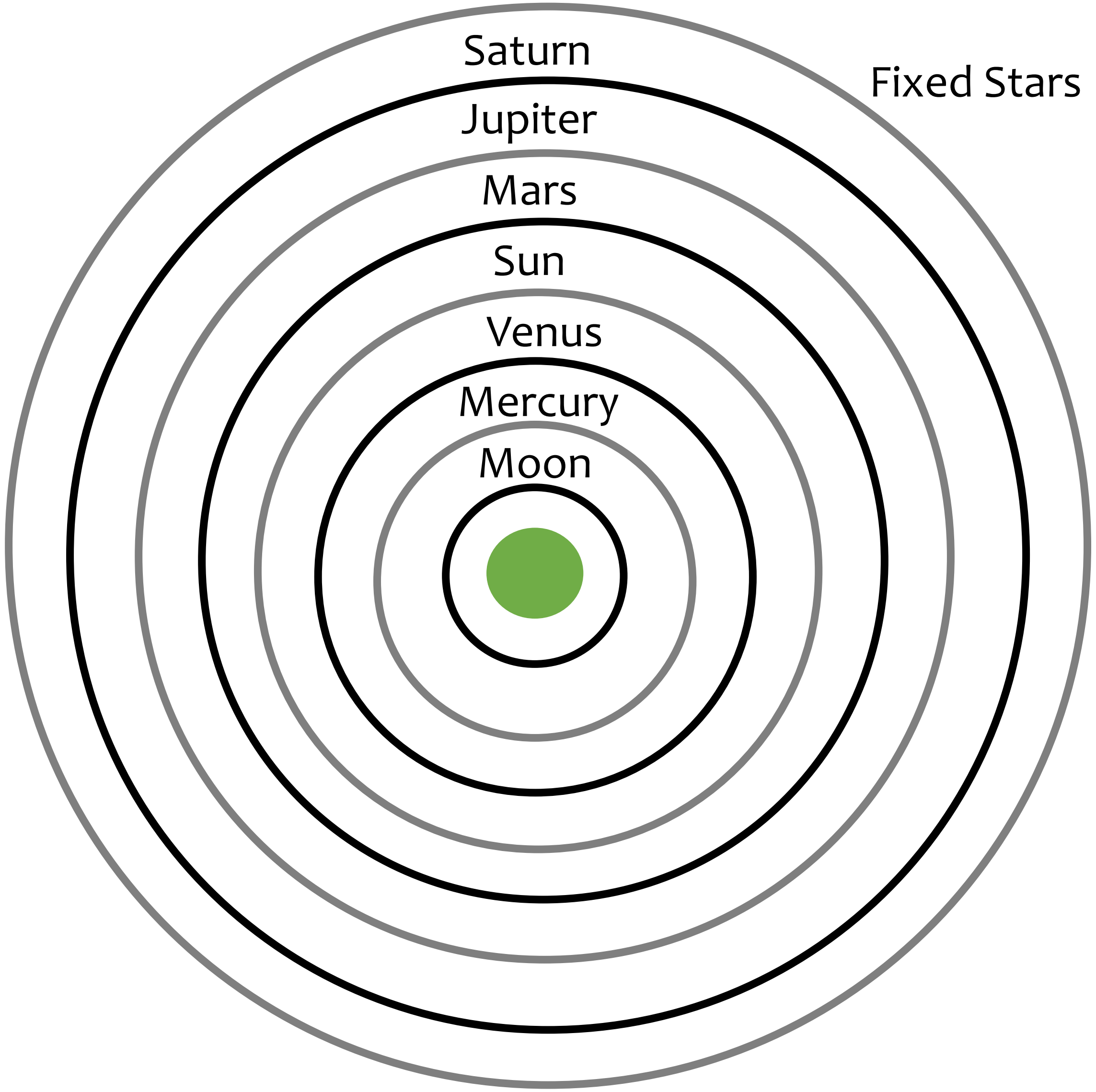
The Problem of the Planets

- For the Aristotelian astronomers, the scientific problem about the planets was ***to predict and explain their drifting motion and retrograde motion***.
  - Explaining in the minimal sense (retrodicting the observed data).
- **The constraints on an acceptable solution to this problem** are:

1. Invoke only uniform circular motions
2. Accurately predict and explain observed motions of the planets
3. Cohere with other, especially core, beliefs of the Aristotelian worldview.

- (1) and (2) play a major role in the development of Ptolemy's solution.

Solving the Problem of the Planets



Ancient astronomers (long before Ptolemy) quickly realized that this system cannot accurately predict planetary motion.

In other words, the theory's prediction did not match the data.

How would scientists respond to this kind of case?

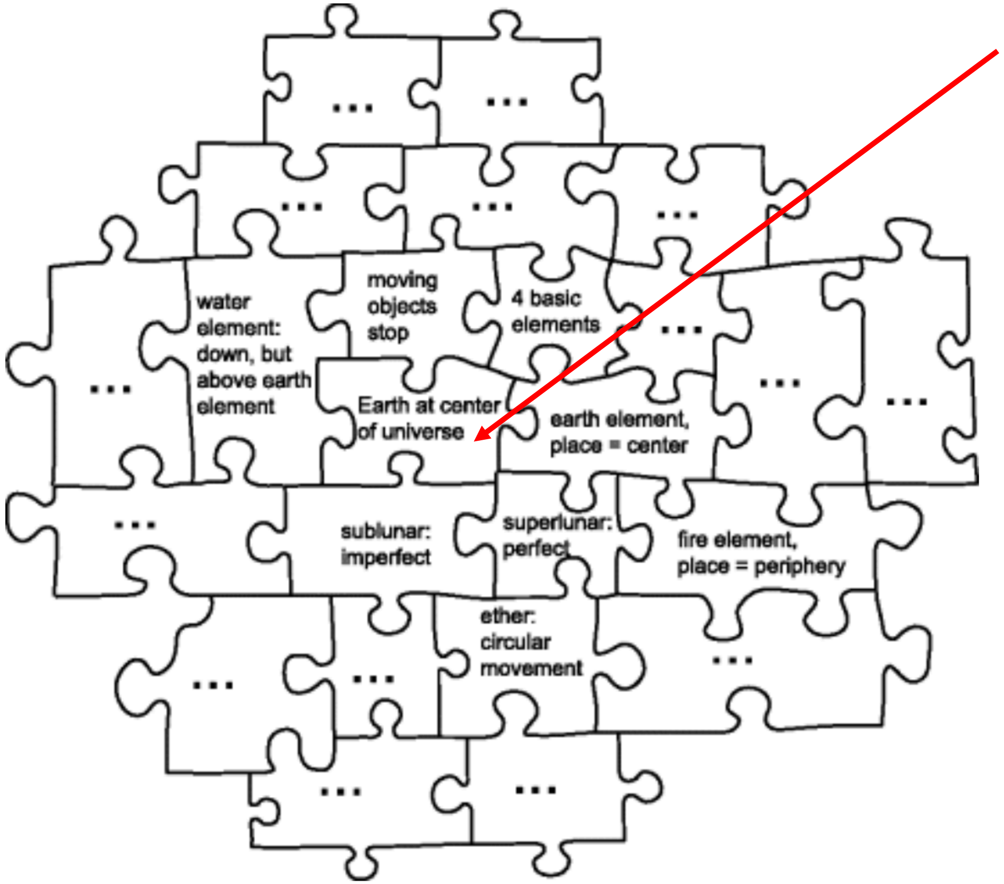
Solving the Problem of the Planets

- Review the structure of disconfirmation reasoning:

1. If **T** and $A_1, \ldots, A_n$, then **O**.
2. Not **O**.
3. So, not **T**, or not A_1, . . ., or not A_n.

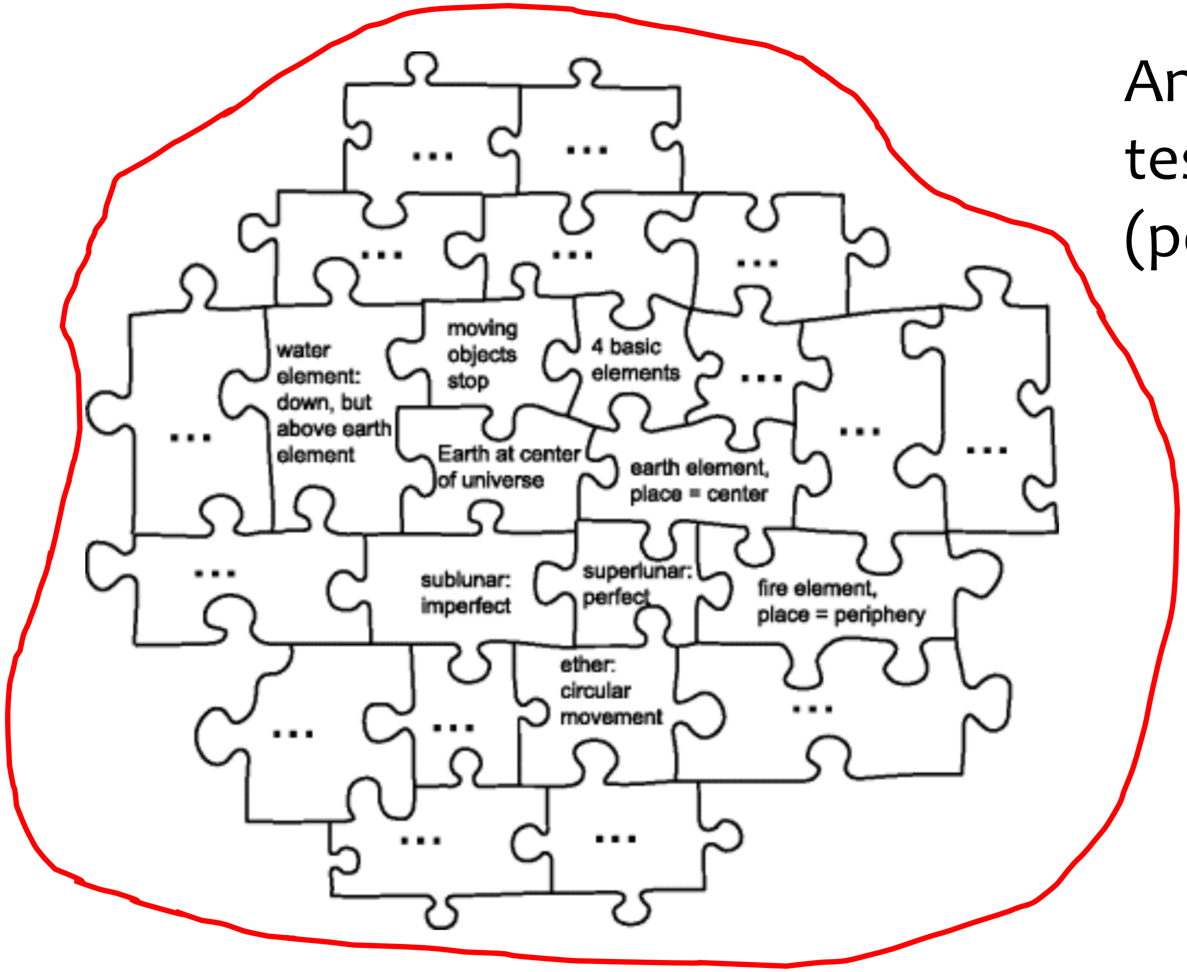
- Let **T** be the simple Aristotelian system of the last slide, and **O** is the observed motions of planets.
- As we discussed, in this situation, scientists can respond by adjusting auxiliary hypotheses (A_1, A_2, etc) rather than completely rejecting **T**.
- We discussed a similar situation regarding the Quine-Duhem thesis (see next).

The Quine-Duhem Thesis (I)



A single puzzle piece is not what is tested against evidence. (Negative part of the thesis)

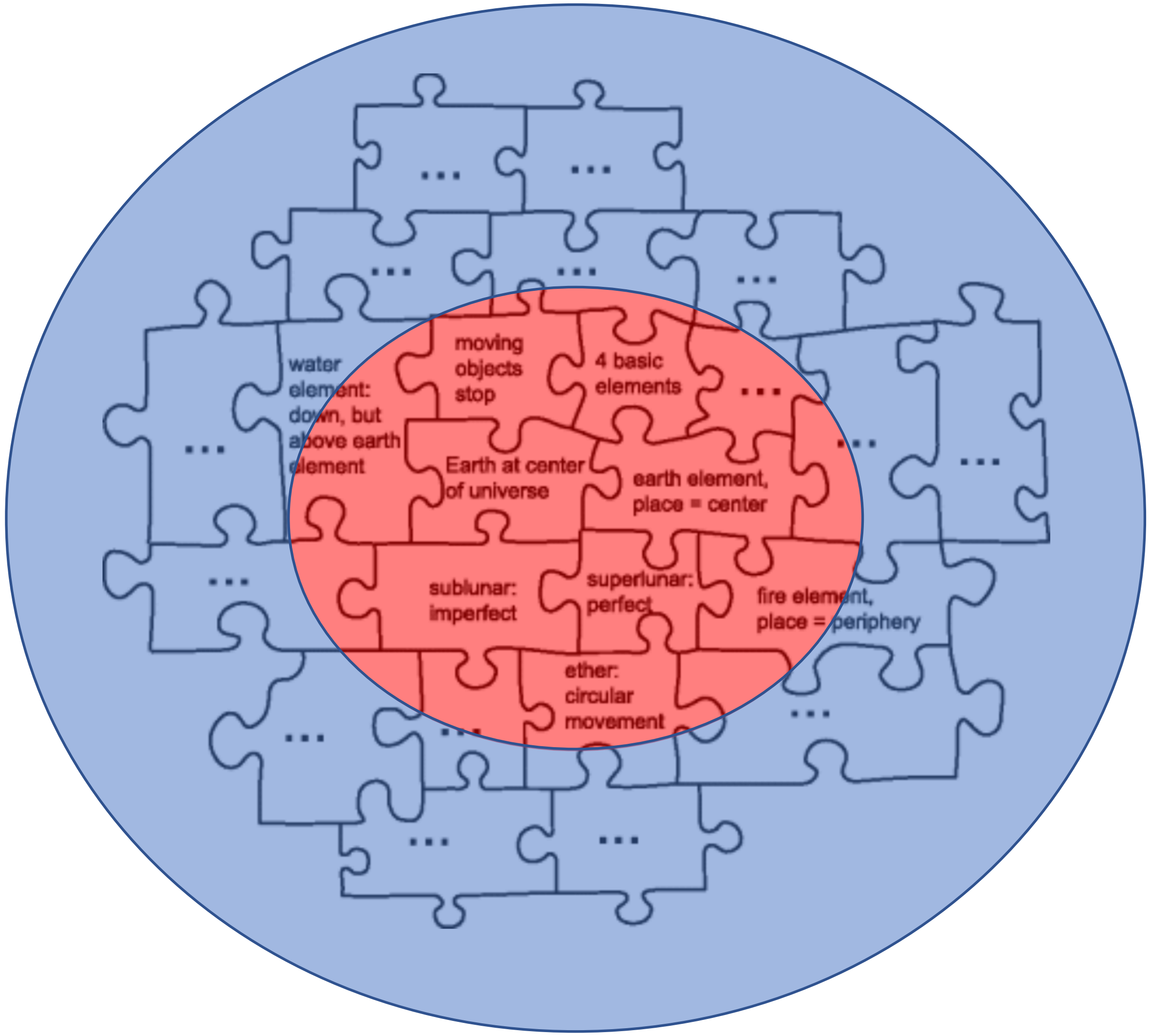
The Quine-Duhem Thesis (I)



An entire puzzle is what is tested against evidence. (positive part of the thesis)

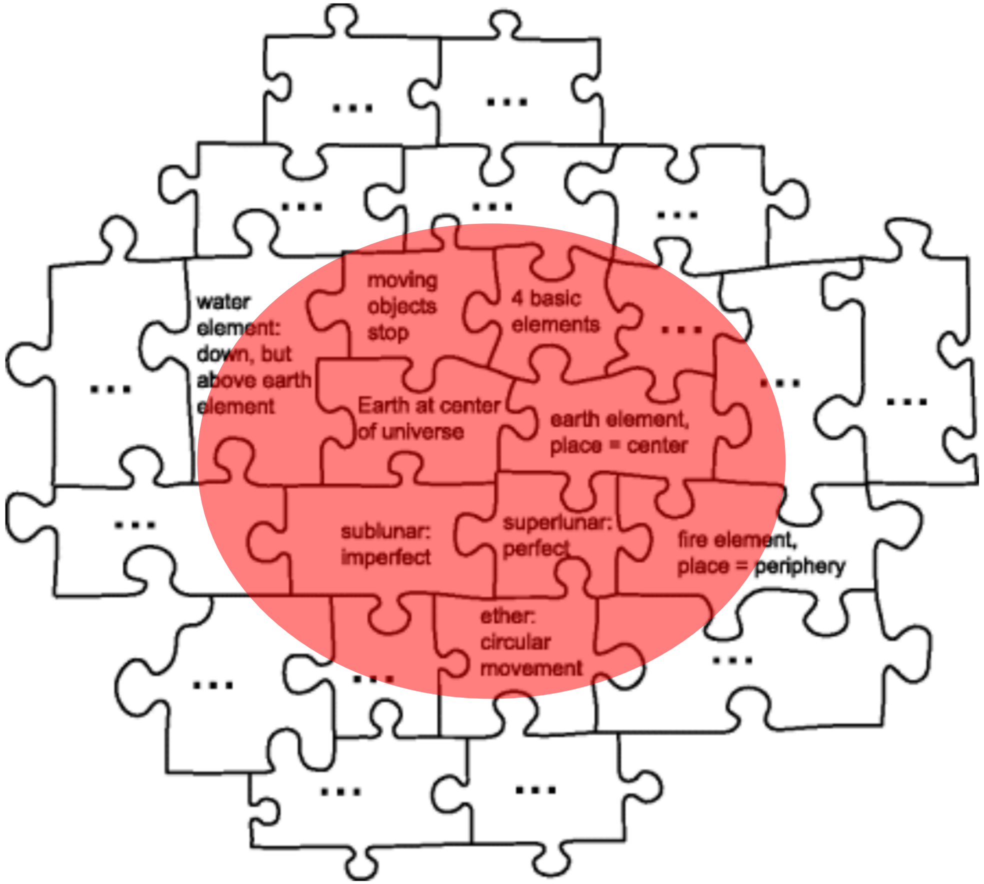
But why is it that a single belief is not what is tested?

The Quine-Duhem Thesis (I)



Recall our discussion of the core and peripheral beliefs.

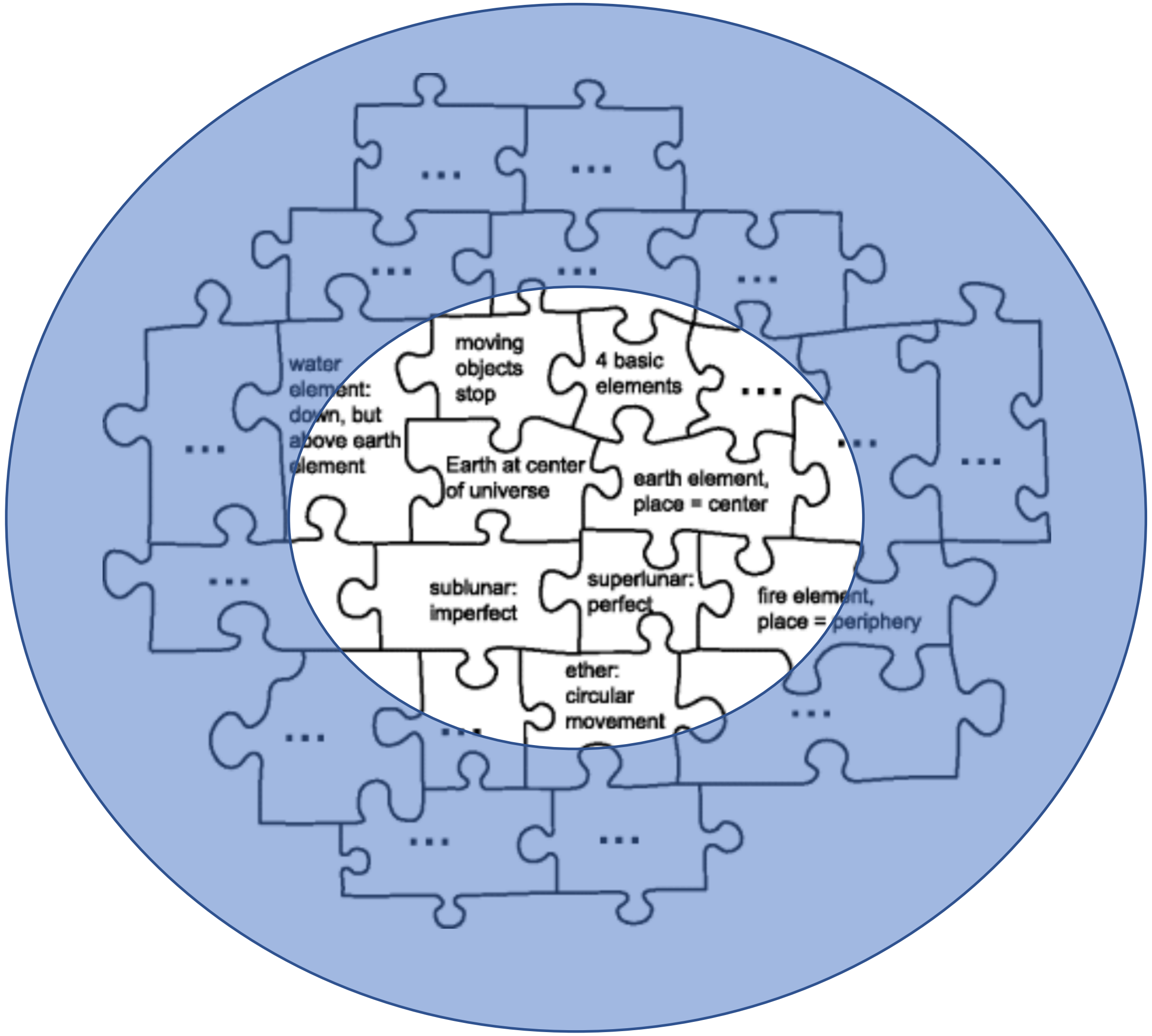
The Quine-Duhem Thesis (I)



Imagine one of the core beliefs is T in the scheme below, and it is challenged by evidence.

If T, then O.
Not O.
So, not T.

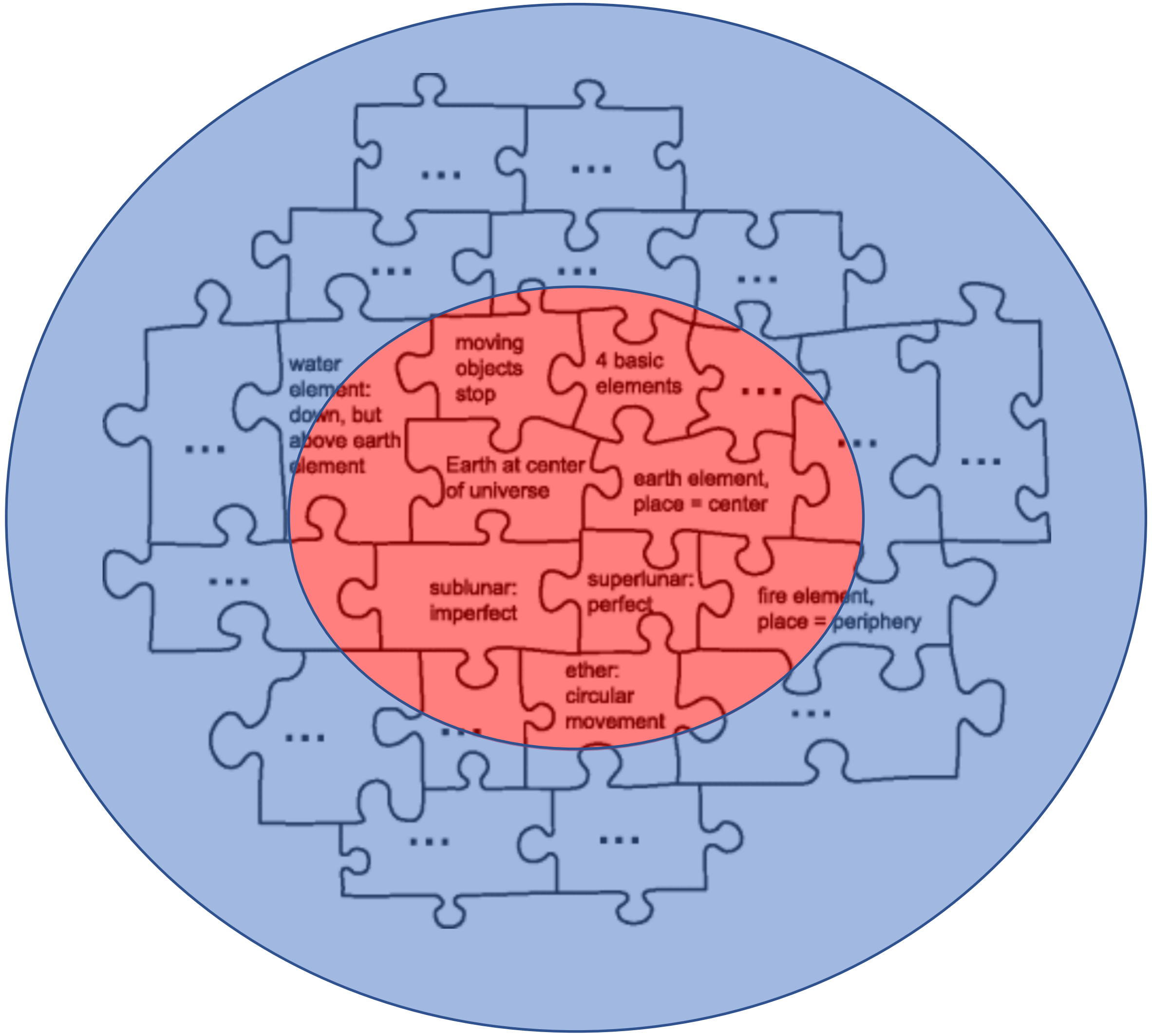
The Quine-Duhem Thesis (I)



But it’s possible to adjust peripheral beliefs to explain the discrepancy between the theory and evidence.

This adjustment allows us to keep the core belief in question.

The Quine-Duhem Thesis (I)



When a core belief of a theory is challenged by evidence, scientists generally look for possible adjustments in the peripheral beliefs.

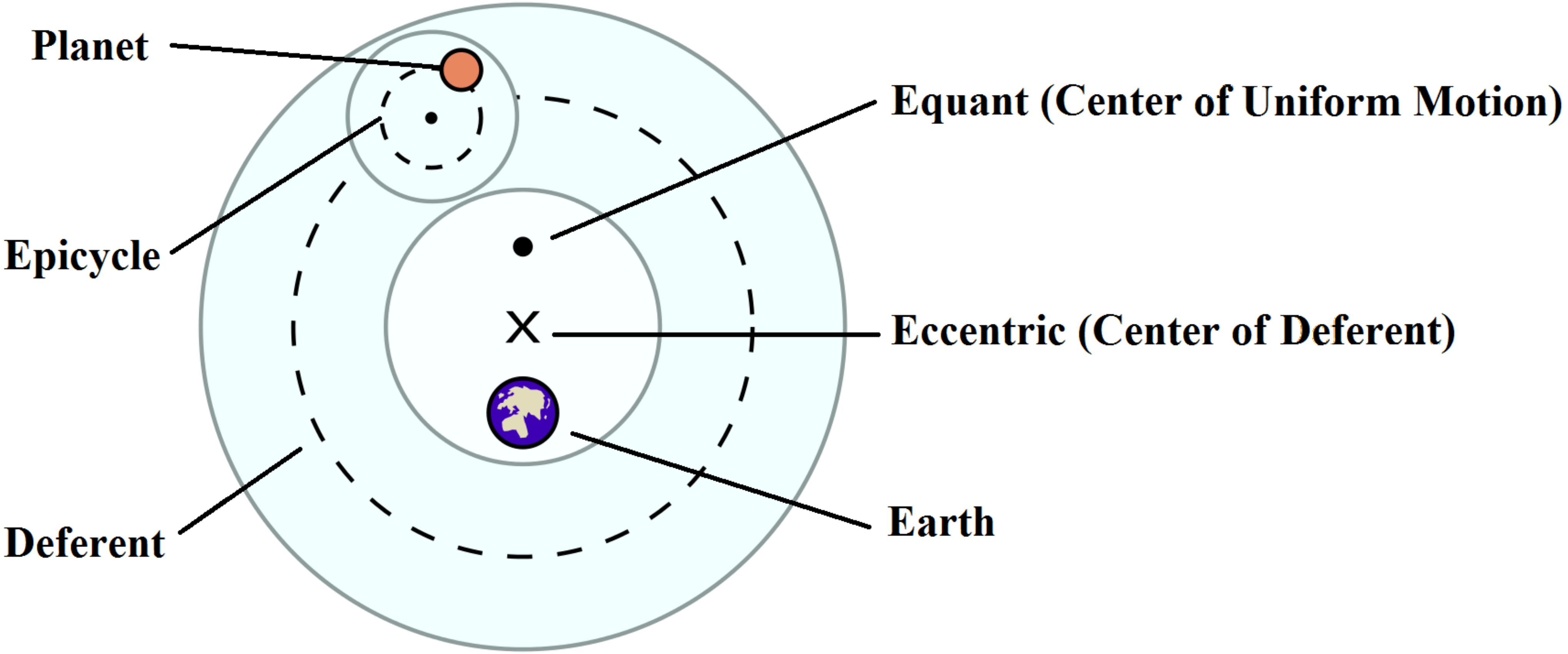
The peripheral beliefs here include auxiliary hypotheses.

Solving the Problem of the Planets

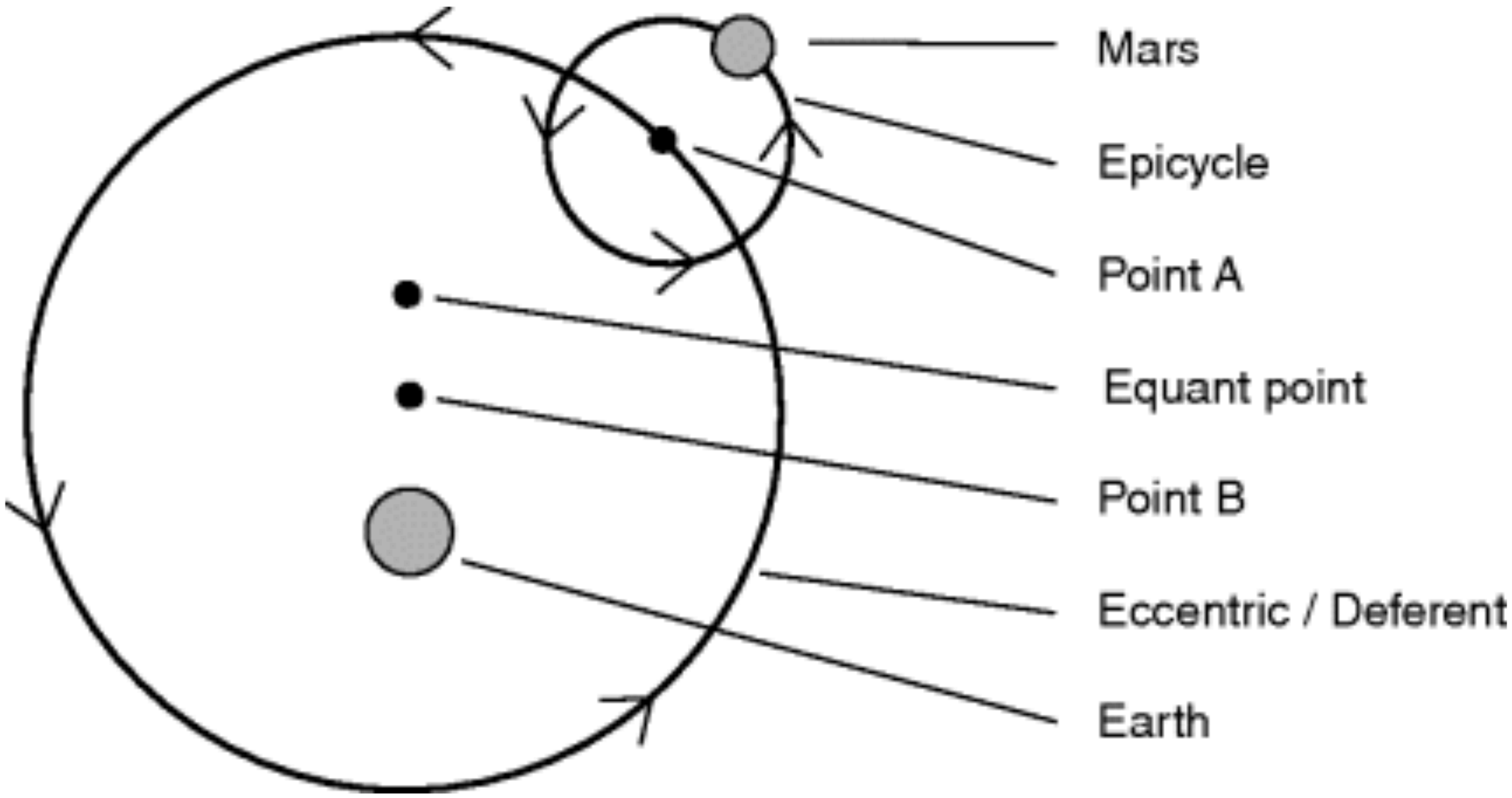
- Ancient astronomers responded by adjusting and adding peripheral beliefs rather than rejecting the core Aristotelian beliefs.
- Before Ptolemy (100–170 CE), Apollonius (240–190 BCE) and Hipparchus (190–120 BCE) proposed an adjustment to the simple Aristotelian system.
- This is **the epicycle-deferent system**.

Quiz 6

Solving the Problem of the Planets



The epicycle-deferent system

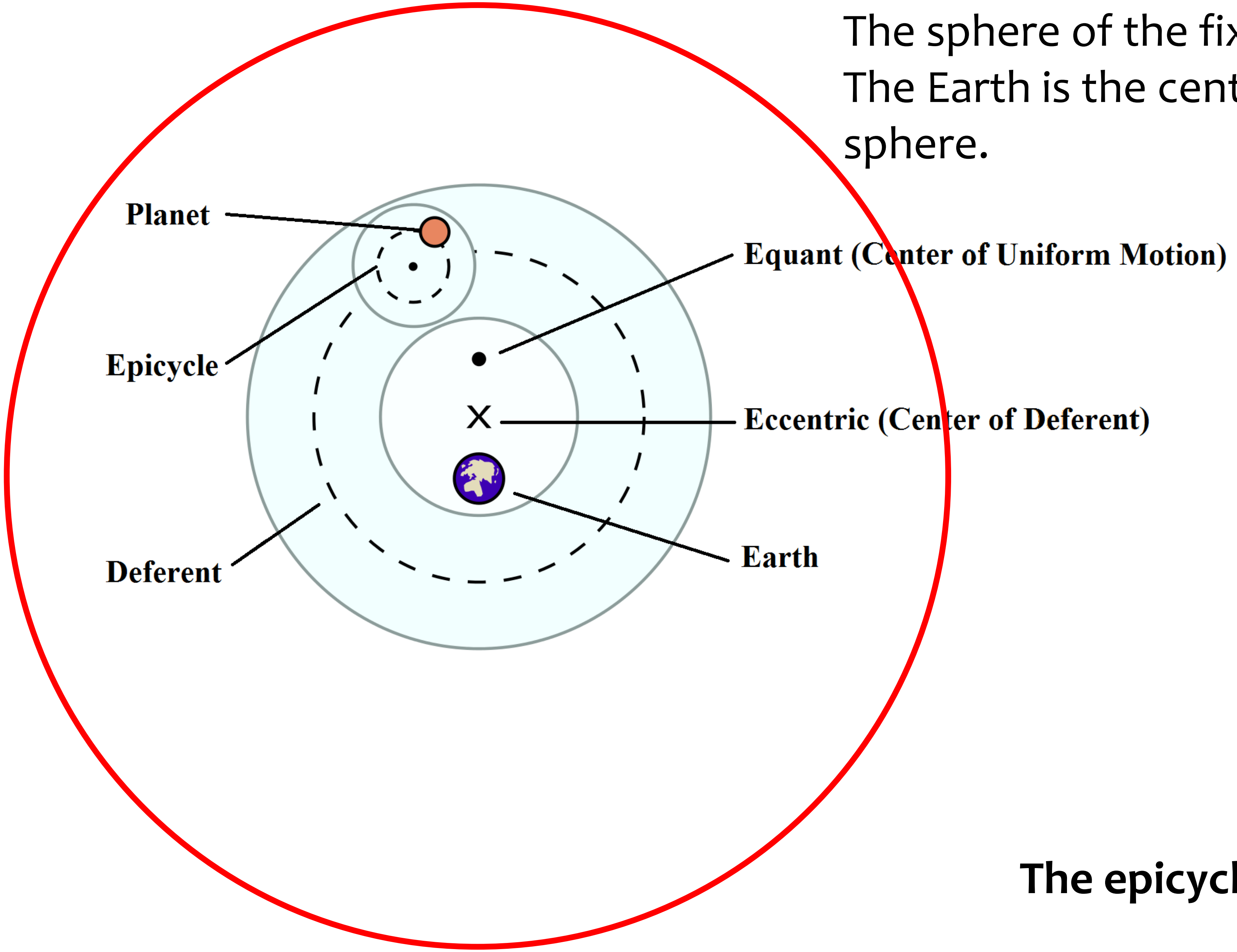


Mars
Epicycle
Point A
Equant point
Point B
Eccentric / Deferent
Earth

Solving the Problem of the Planets

- In the diagram, the Earth looks off-center, but what is off-center is the center of a deferent.
- The Earth itself is at the center of the sphere of the fixed stars (which is the outermost sphere of the universe), so it is at the center of the universe. (See next)

The sphere of the fixed stars. The Earth is the center of this sphere.



The epicycle-deferent system

Solving the Problem of the Planets

- Recall the constraints:
- **The constraints on an acceptable solution to this problem** are:

1. Invoke only uniform circular motions
2. Accurately predict and explain observed motions of the planets
3. Cohere with other, especially core, beliefs of the Aristotelian worldview.

- Focus on (1) and (2). Does the epicycle-deferent system satisfy these constraints?

Solving the Problem of the Planets

1. Invoke only uniform circular motions

- All the epicycles and deferents are perfect circles.
- But planetary motion is *not uniform* with respect to the eccentric (the center of a deferent).
- Ptolemy tried to solve this discrepancy with an equant point (we'll discuss this next time).
- The important point now is that this constraint can be met by the epicycle-deferent system.

Solving the Problem of the Planets

2. *Accurately predict and explain observed motions of the planets*

- Ptolemy's *Almagest* (150 CE) provided a mathematical (geometrical) theory of the epicycle-deferent system that met this constraint remarkably well.
- The epicycle-deferent system had enough flexibility to match the observed data.
    - We'll talk about this flexibility next.
- The epicycle-deferent system also explained retrograde motion.

Solving the Problem of the Planets

- One way to understand the *flexibility* of a theory to match observed data is to focus on ***the adjustable parameters*** of the theory.
- An adjustable parameter is an element of a theory that can be finetuned by comparison with the data.
- Increasing the number of adjustable parameters tends to increase the theory's ability to match the data. (illustration below)
- https://phet.colorado.edu/sims/html/curve-fitting/latest/curve-fitting_en.html

Solving the Problem of the Planets

- The epicycle-deferent system has several adjustable parameters. A few examples:

1. Size of an epicycle
2. Eccentricity (how off-center the deferent is)
3. Speed of rotations, etc . . .

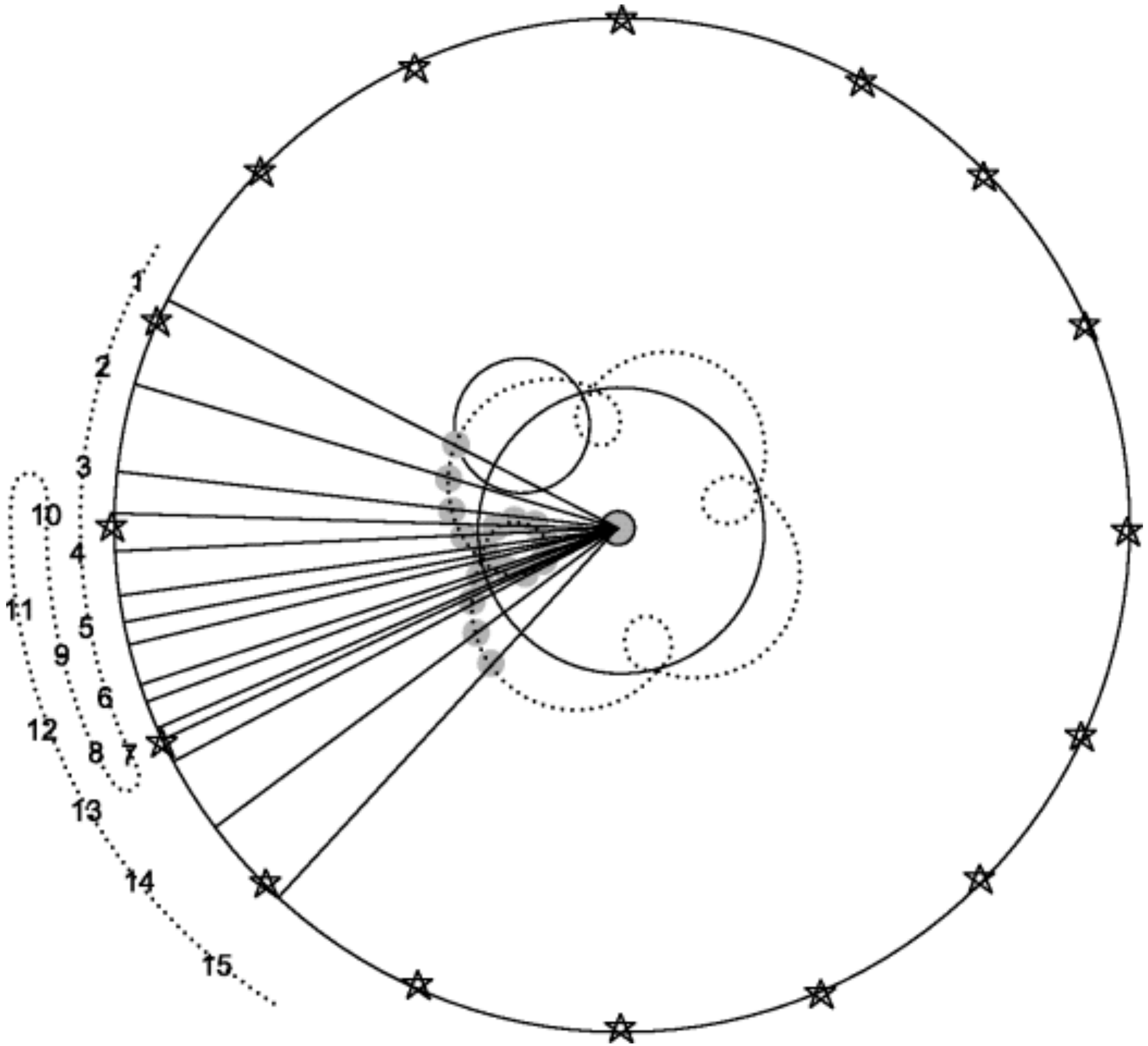
- By adjusting these parameters, the system can be matched to the observed data about planetary motion.
- https://www.foothill.fhda.edu/astronomy/astrosims/ptolemaic-system/index.html
    - (See next for things to try with this simulator)

Solving the Problem of the Planets

- Things to try with this simulator.

1. Set all parameters to 0, except motion rate. This is like the simple Aristotelian system.
2. Find the parameter set that does NOT produce retrograde motion.
3. Find the parameter set that does produce retrograde motion.

- You can see that the epicycle-deferent system also explained retrograde motion.


1
2
3
10
4
11
5
9
6
12
8
7
13
14
15

Solving the Problem of the Planets

- In the Ptolemaic astronomy, planets exhibit retrograde motion because they actually move back and forth in the sky.
- This is like how we would ordinarily explain why a flash light moves back and forth in the distance in a dark night.
  - We would think that the light (the person holding the light) is actually moving back and forth.