02. Logic and Empiricism

1. Classical Empiricism

(Locke, Berkeley, Hume ~1700's)

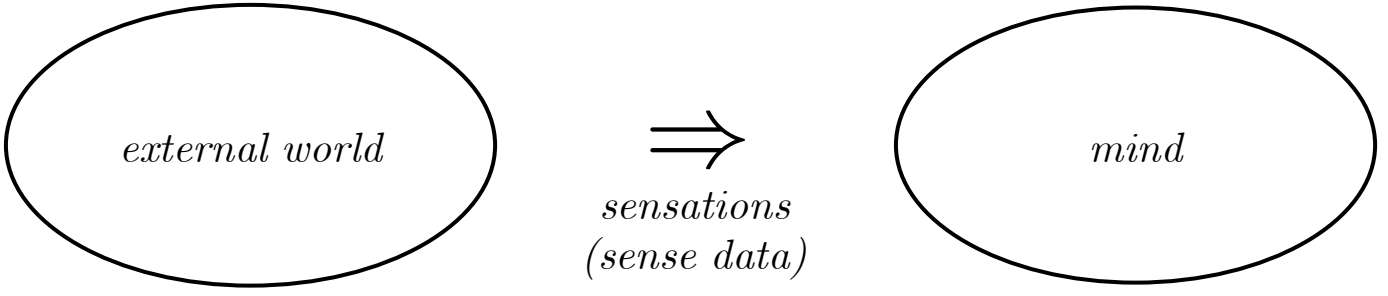

John Locke (1632-1704)


George Berkeley (1685-1753)


David Hume (1711-1776)

Claim: The only source of knowledge of the external world is experience.

- *Sensationalism*: Experience of the external world consists of pre-structured sense data impinging on the mind.



- *passively receives sense data*
- *initially "empty" (blank slate)*

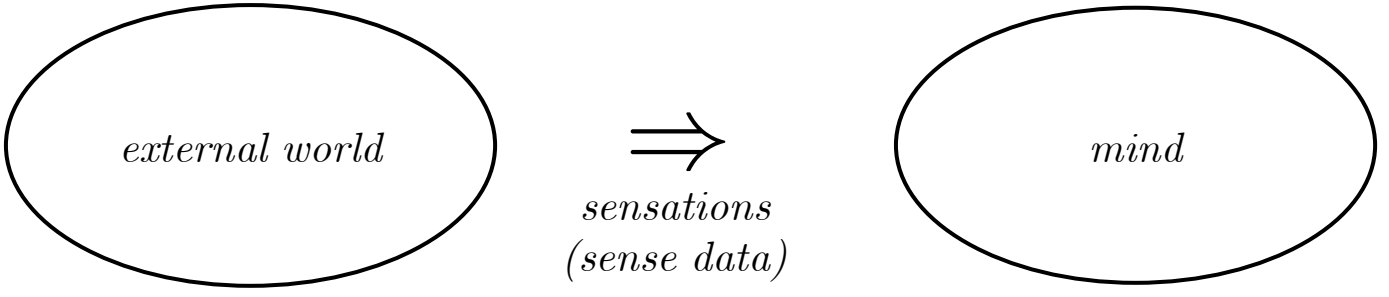
- *External World Skepticism*: How is knowledge of the source of sense data (the external world) possible? How can we know anything behind the appearances (sense data)?
- *Inductive Skepticism:* How is knowledge of the future based only on past experience possible?

2. Rationalism

Claim: There can be certain knowledge based on pure reason alone (in addition to knowledge based on experience).

- *a priori* knowledge = certain knowledge independent of experience.
- *Example*:
  - Rene Descartes (1600's): *Cogito ergo sum* (I think therefore I am).

Rene Descartes
(1596-1650)

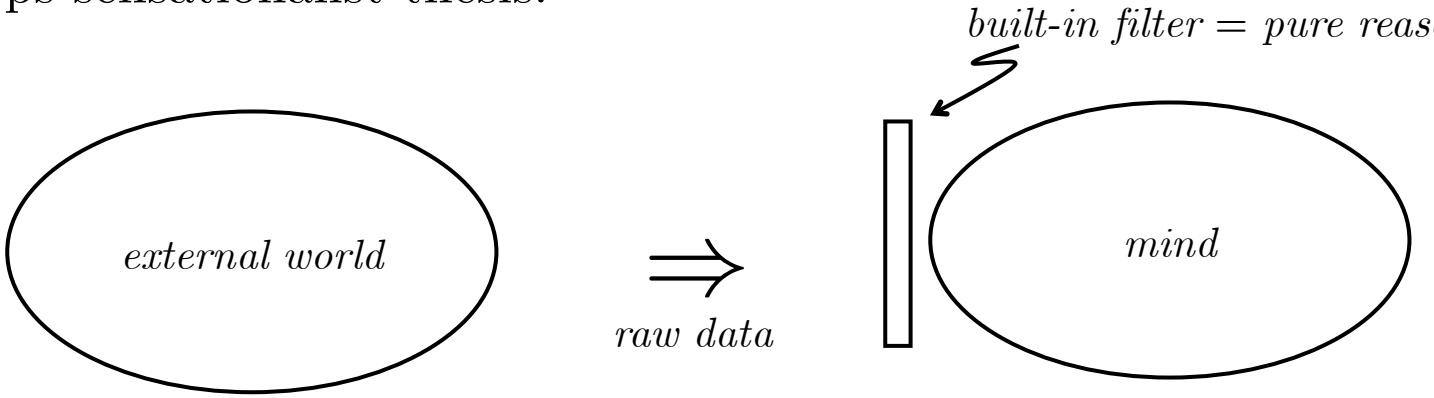


- *passively receives sense data*
- *initially non-empty: some knowledge of external world possible prior to experience*

3. Emmanuel Kant (1700's)

Emmanuel Kant
(1724-1804)

- An attempt to combine empiricist and rationalist theses.
- Drops sensationalist thesis.



The "noumenal world"

- *unstructured*
- *unordered*

- *actively receives raw data*
- *distintion between content (raw data; initially empty) and form (data filters; initially present)*

- Raw data has no structure or order.
- All structure and order (causal, temporal, spatial, etc) is imposed on raw data by filters ("forms") already present in the mind.
- Knowledge generated by such forms is *a priori* (*i.e.*, certain).
- Filtered data (structured, ordered) constitutes experience (the "phenomenal world").

4. Logical Positivism (1920's–1930's)


Rudolph Carnap (1891-1970)


Moritz Schlick (1882-1936)


Otto Neurath (1882-1945)


Hans Hahn (1879-1934)


Hans Reichenbach (1891-1953)


Ludwig Wittgenstein (1889-1951)

Four Key Ideas...

Key Idea #1: Analytic-Synthetic Distinction

- *analytic sentence* = a sentence that is true/false in virtue of its meaning.

  Ex: A bachelor is an unmarried man.

- *synthetic sentence* = a sentence that is true/false in virtue of its meaning *and* how the world actually is.

  Ex: All bachelors are dorky guys with roses.

Logical Positivist Critique of Kant

- *Kantian Claim*: Euclidean geometry is *synthetic* *a priori* knowledge.

has factual content

knowable with certainty prior to experience

- 1800's: Development of non-Euclidean geometries.
  - *analytic* *a priori* exercises in pure mathematics

- 1910's: Physical applications of Non-Euclidean geometries.
  - special relativity (non-Euclidean flat geometry)
  - general relativity (non-Euclidean curved geometries)

- Logical Positivist moral: Distinction between:
  (a) pure mathematics = *analytic* *a priori*
  (b) applied mathematics = *synthetic* *a posteriori*

known through experience

Claim: No such thing as *synthetic* *a priori* mathematics in particular, and *synthetic* *a priori* knowledge in general.

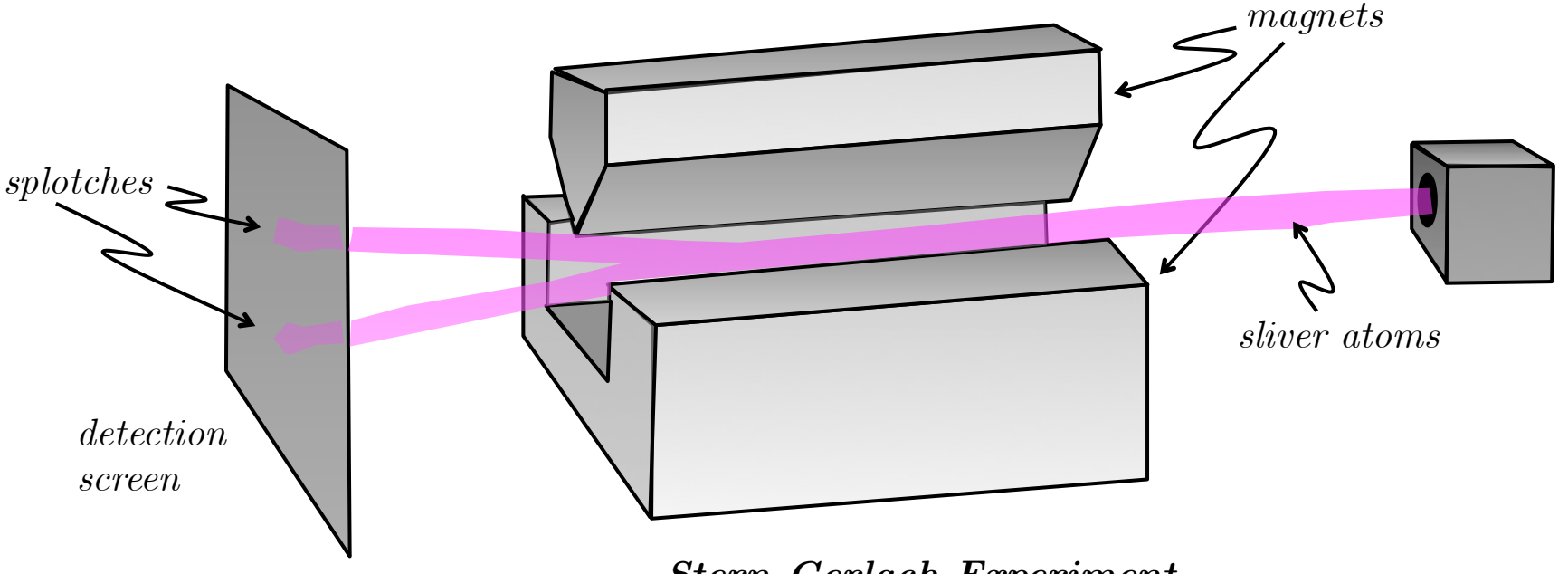
Key Idea #2: Verifiability Theory of Meaning

> *Claim:* The meaning of a sentence consists in its method of verification.
> (*Or*: If a sentence has no method of verification, it has no meaning.)

- Scientific claims about the world are verifiable, hence meaningful.
- Non-scientific claims about the world are not verifiable, hence meaningless.
- *Examples*:
  - "God exists."
  - "Human history is a process of the unfolding of the Absolute Spirit."
  - "The electron has a charge to mass ratio of $1.758820150 \times 10^{11} C/kg$."
  - "9,872,356,143 angels can dance on the head of a pin."
  - "Mutations in the BRCA1 and BRCA2 genes are linked to breast and ovarian cancer."

Key Idea #3: Observational & Theoretical Languages

- Two parts to the language in which scientific theories are presented.
- *Theoretical part:* referants are unobservable things.
  - *theoretical term*: "electron"
  - *theoretical claim*: "The electron has spin 1/2."
- *Observable part*: referants are observable things.
  - *observational term*: "splotch of light"
  - *observational claim*: "There are two splotches of light on the detection screen."



Stern-Gerlach Experiment

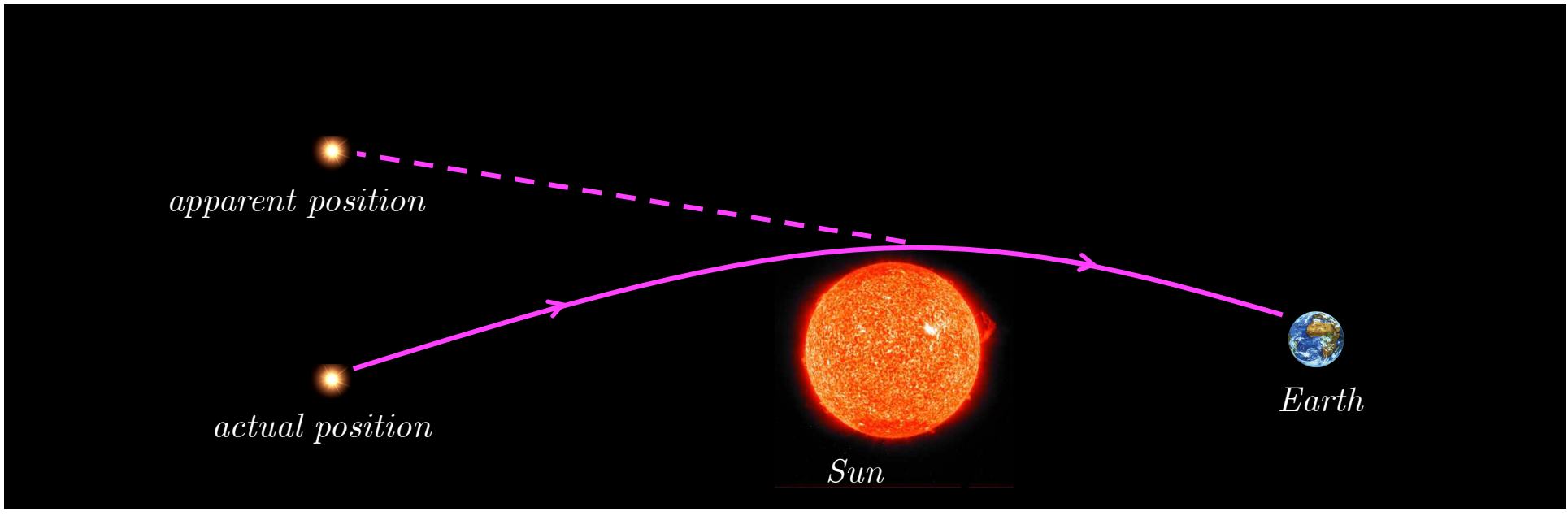
Key Idea #4: The Role of Logic

- 1st-order logic is a very simple formal language: little room for ambiguity or vagueness.
- *Thus*: To understand scientific reasoning and methodology, analyze the language of science in terms of 1st-order logic.

Two types of reasoning:
- *Deductive* = truth of premises *guarantees* truth of conclusion.
- *Inductive* = truth of premises *lends support to* truth of conclusion.

- Deductive logic is well-established (early 20th century).
- Inductive logic is not!

- *One goal of logical positivism*: Develop an inductive logic to apply to scientific reasoning.
  - *Why?* Scientific reasoning combines elements of *both* deductive and inductive reasoning.



- *Drawing predictions from hypotheses* = deduction
  - *Example*: 1910 - Einstein uses general relativity to predict that light rays bend around Sun.
- *Using evidence to confirm hypotheses* = induction
  - Photograph star field at different times of year and see which stars are shifted. Einstein's prediction: deflection of 1.75 *sec of arc.*
  - To correct for sun's glare, take photos during solar eclipse.
  - 1919 - Eclipse Expedition led by Sir Arthur Eddington to S. America and S. Africa confirms prediction.
  - GR is "confirmed" (but this doesn't guarantee it's truth).

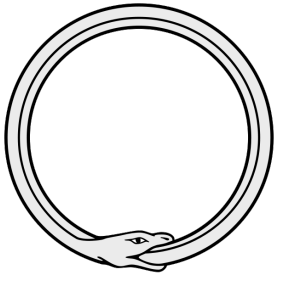
Emphasis on logical analysis also motivates distinction between...

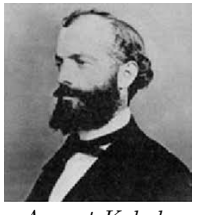
> *Context of Discovery* = context in which theories are *discovered*.
>
> *Context of Justification* = context in which theories are *justified*.

Context of Discovery

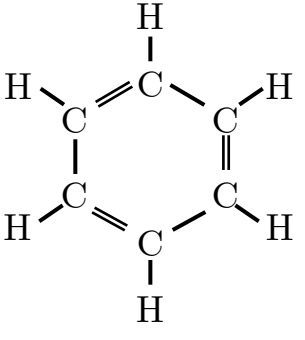
- Not a part of philosophy of science.
- Leave it to psychologists, historians, sociologists, *etc.*
  - Newton and the apple.
  - Kekule and structure of benzene molecule:

    I turned my chair to the fire [after having worked on the problem for some time] and dozed. Again the atoms were gamboling before my eyes. This time the smaller groups kept modestly to the background. My mental eye, rendered more acute by repeated vision of this kind, could not distinguish larger structures, of manifold conformation; long rows, sometimes more closely fitted together; all twining and twisting in snakelike motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lighting I awoke... Let us learn to dream, gentlemen.





August Kekule
(1829-1896)



Context of Justification

- Proper subject of study for philosophy of science.
- Requires logical analysis of confirmation.

Two Problems with Logical Positivism

(1) Issues with the Verifiability Theory of Meaning.

(a) It's too weak!

- *Suppose*: A sentence is verifiable if we can empirically show that it is false.
- *Then*: "All metals expand when heated" is verifiable.
  - We can empirically show that this is false.
- *Consider*: "All metals expand when heated and the Absolute Spirit is perfect".
- *Note*: Since we can empirically show that the first conjunct is false, we can empirically show that the entire conjunction is false (a conjunction is false just when one of its conjuncts is false).
- *So*: The entire conjunction is verifiable, and thus meaningful!

Negative thermal expansion:
- cubic zirconium tungstate
- water below 3.984C
- silicon between 18K and 120K
- *etc.*

Two Problems with Logical Positivism

(1) Issues with the Verifiability Theory of Meaning.

(b) It's too strong!

- *Suppose*: A sentence is verifiable just when it can be judged to be true or false by means of a direct observational test.
- *Note*: The following claims cannot be judged true or false by means of a direct observational test:
  - "Superstrings exist."
  - "Once information gets into protein, it can't flow back to nucleic acid."
  - "The meaning of a sentence consists in its method of verification."
- *So*: Such claims are meaningless!

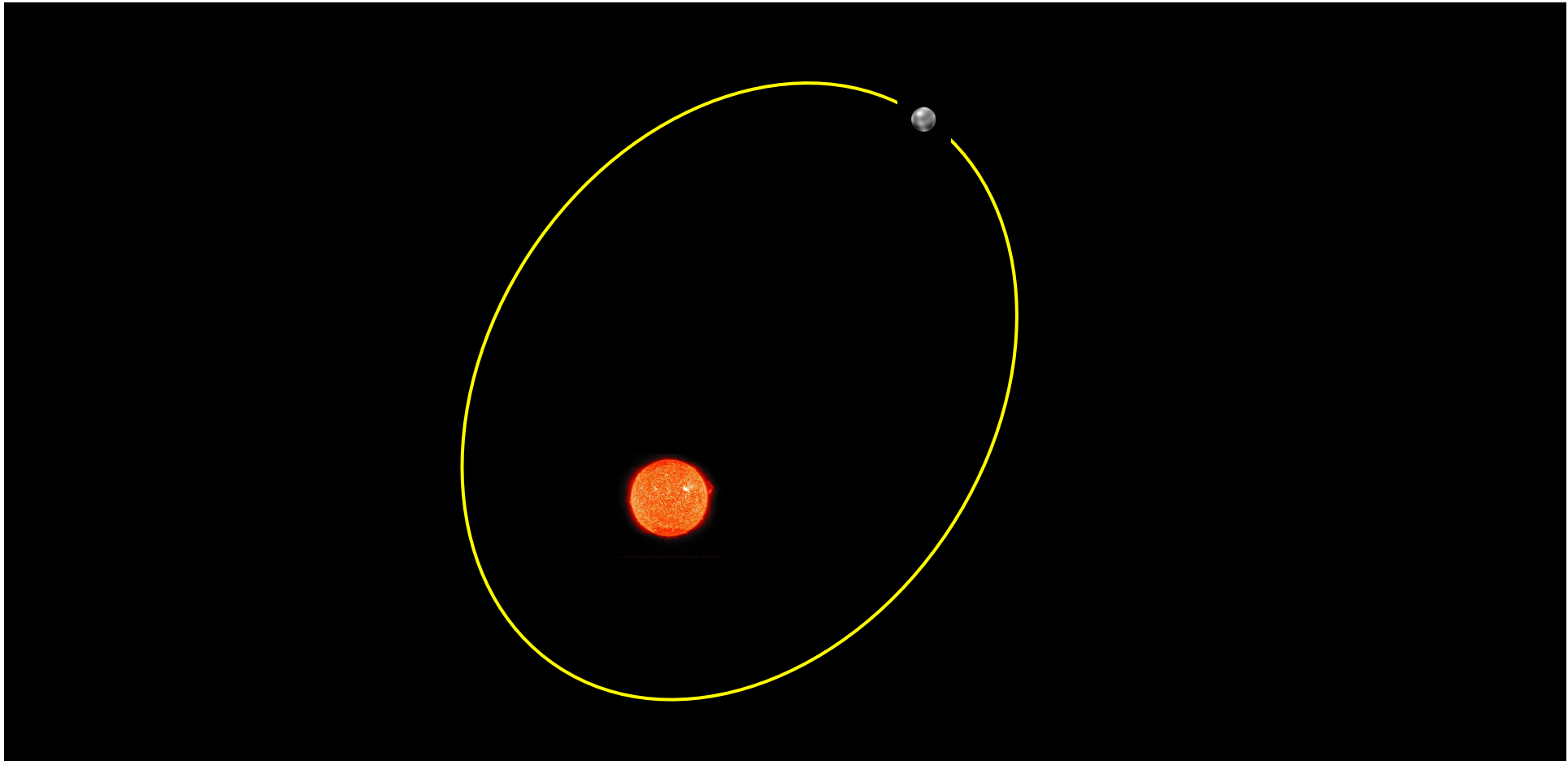
(c) Can a coherent notion of "testability" be defined?

- Depends crucially on the notion of *observation*.
- How are inferences to observable things any different from inferences to unobservable things?

(2) The Duhem–Quine Thesis

Claim: Hypotheses cannot be tested in isolation.

- *Example*: GR prediction: Mercury's orbit precesses by 43 seconds of arc per century.



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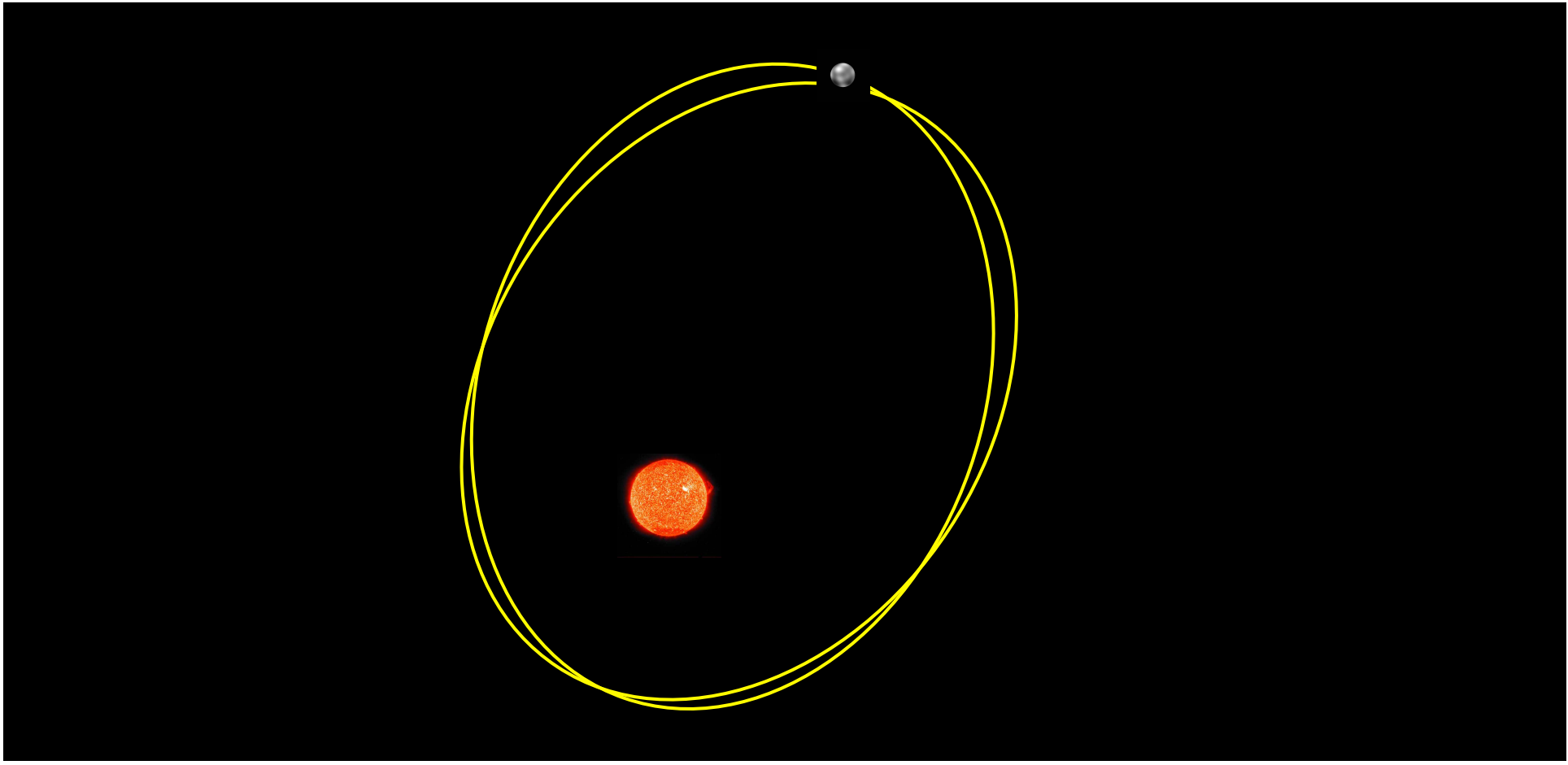

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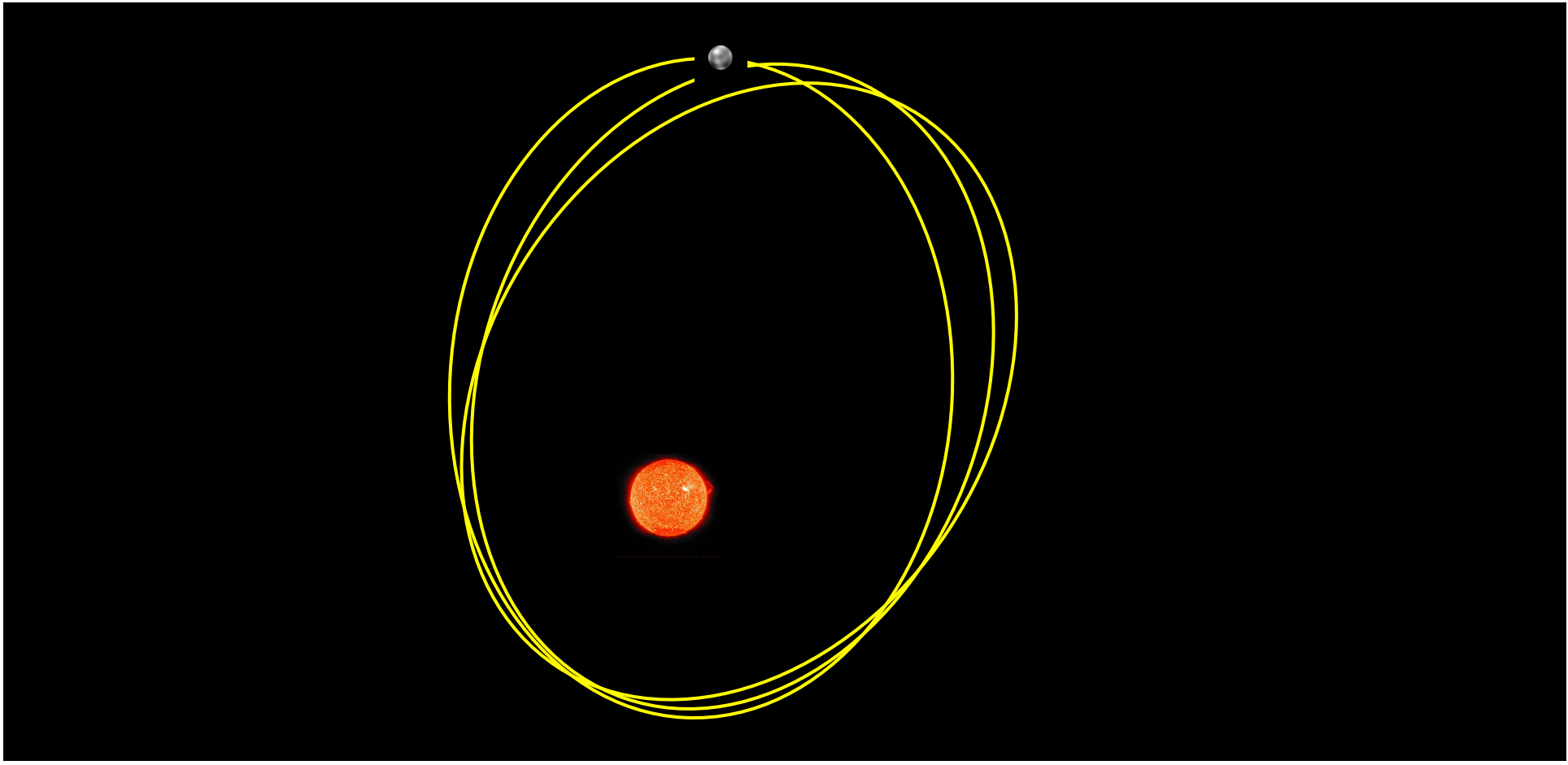

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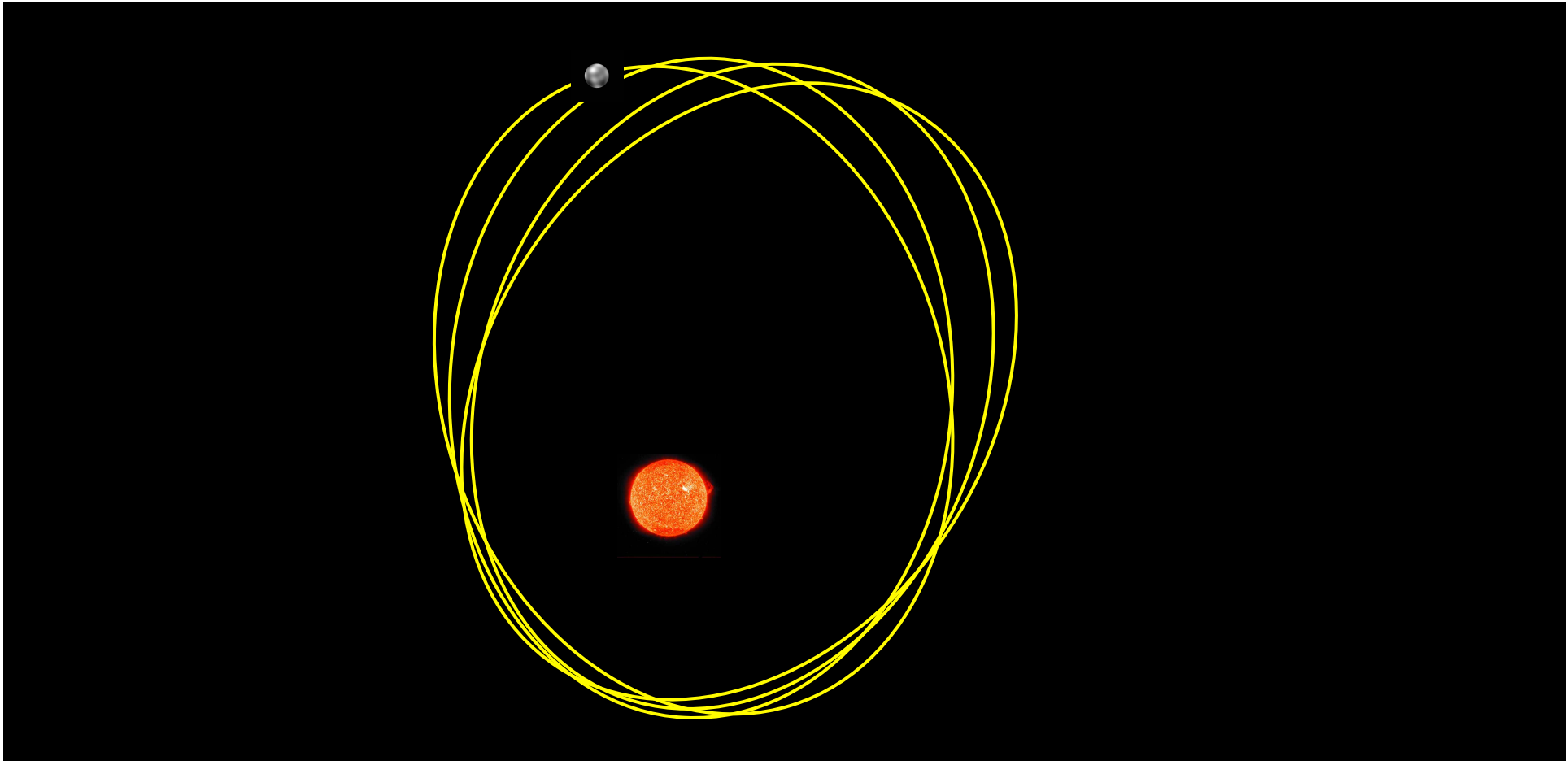
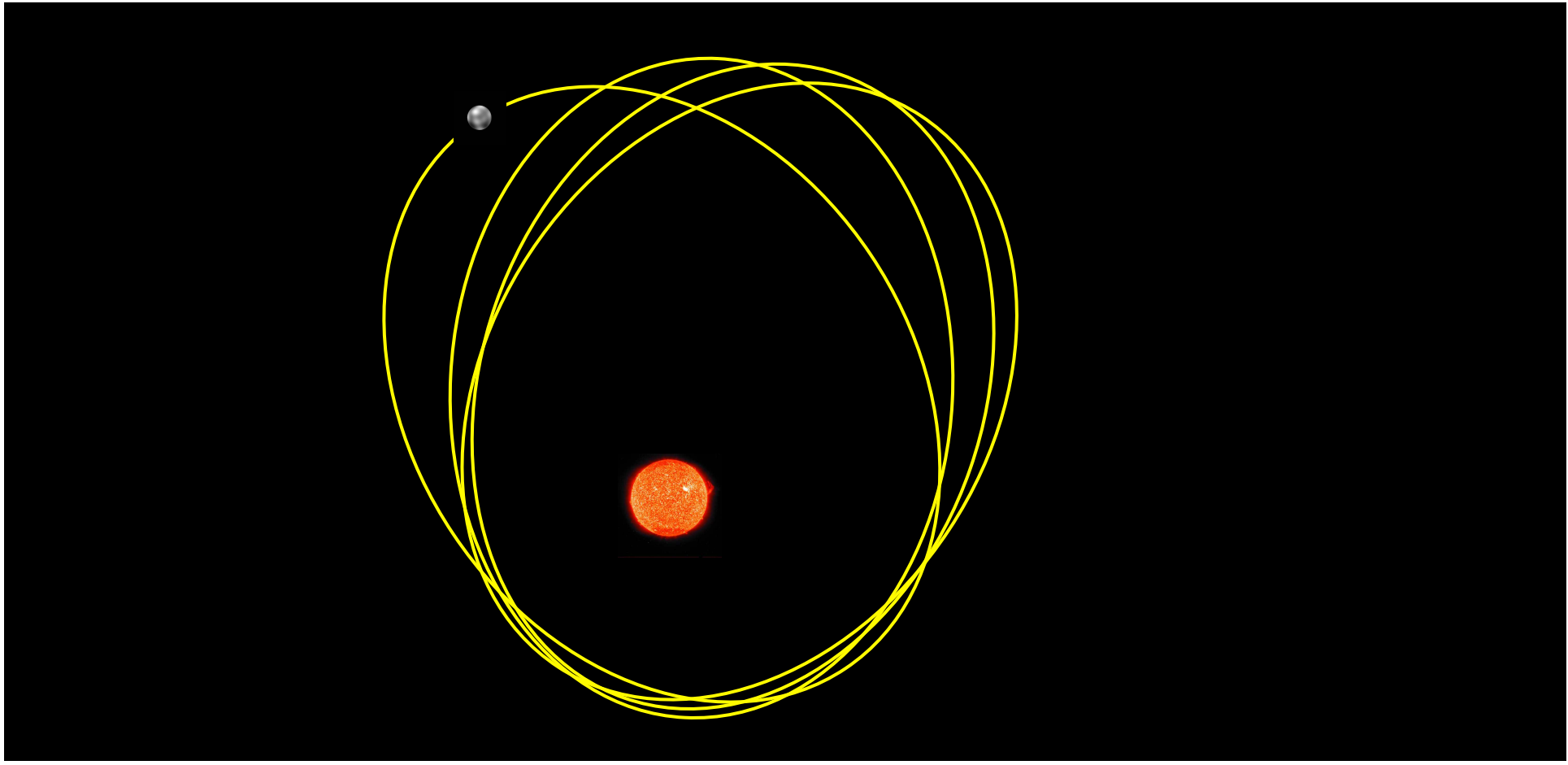


(2) The Duhem–Quine Thesis

Claim: Hypotheses cannot be tested in isolation.

- *Example*: GR prediction: Mercury's orbit precesses by 43 seconds of arc per century.
- Observational data on Mercury indicates this is true.

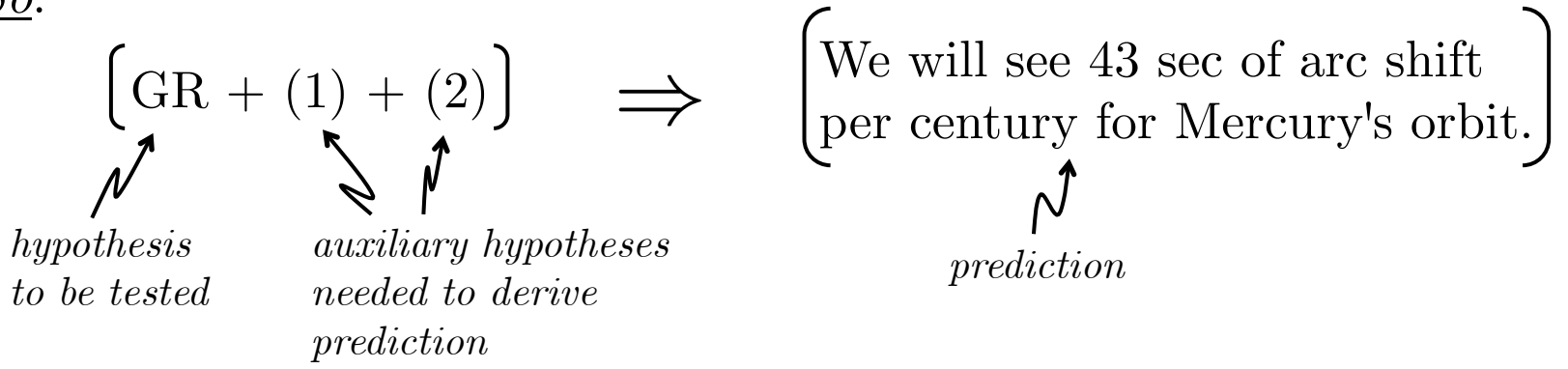


But:

(1) Assumes Sun is perfectly spherical.

(2) Assumes measuring instruments used to chart Mercury's orbit are reliable.

So:



- Prediction is true. But which of GR, (1), and/or (2) does it confirm?
- DQ Thesis: GR cannot be tested in isolation from other claims/beliefs.
- *Consider*: Suppose prediction turned out to be false. Which of GR, (1) and/or (2) should we *blame*? Can we always revise our claims/beliefs to accomodate any new evidence?

DQ Thesis is a problem for:

(a) Verifiability Theory of Meaning.

- VTM assumes claims (sentences) can be tested in isolation.

(a) Analytic/Synthetic Distinction.

Extreme DQ Thesis: Nothing is immune to revision, not even analytic statements.

Quine's "web of belief":

- Scientific claims, common beliefs and opinions, are all interconnected in a single unified *belief system*.
- Changes in any part of the system can be accomodated by revision elsewhere. (It confronts experience as a whole.)

Example: Even logic isn't immune to revision.

- Classical logic - patterned on structure of classical physics.
- Move from classical to quantum physics requires analogous move from classical to quantum logic!

4. Logical Empiricism (1930's–1960's)

Hans Reichenbach (1891-1953)

Carl Hempel (1905-1997)

Herbert Feigl (1902-1988)

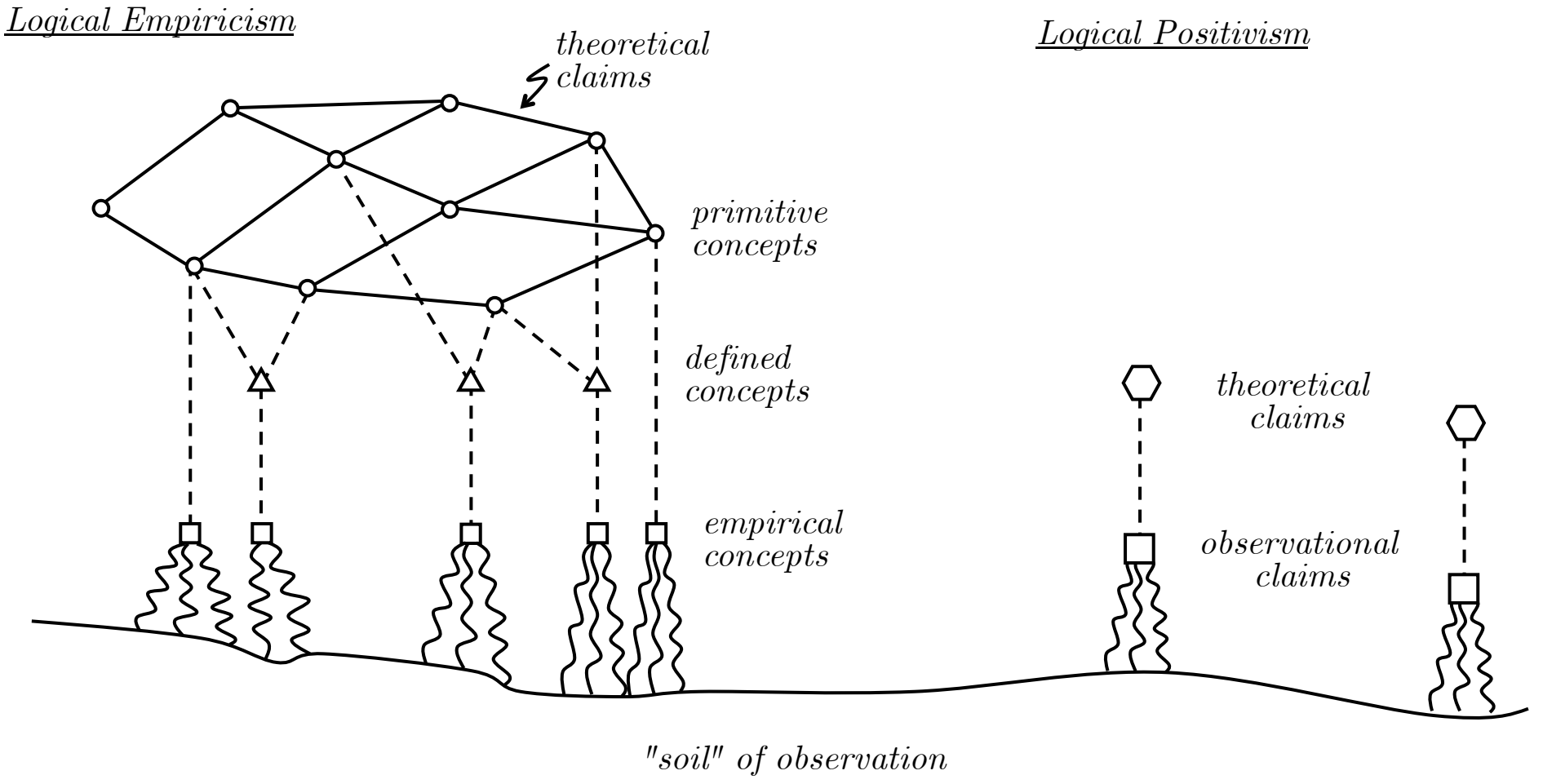
- Watered down version of logical positivism.
- Verifiability Theory of Meaning replaced with...

Holistic Empiricist Theory of Meaning

Theoretical claims about unobservable phenomena gain meaning from their place in the structure of a given theory.

- *Example*: "Electrons have spin 1/2" is meaningful only in the context of a theory of electrons.

View of Theories



Still common to both:

- The role of theoretical claims is *simply* to organize observational claims.
- A theory is *simply* a way of organizing and systematizing data.
- <u>*So*</u>: Theoretical claims about unobservable things are *not* to be taken literally.

- "quark" = theoretical term occuring in theories in particle physics.
  - Only a theoretical tool that's useful in organizing data in scattering experiments.
  - Doesn't refer to anything in the world.

- "gene" = theoretical term occuring in theories in biology.
  - Again: a useful fairy tale to tell about data in biochemical experiments.

"In science there are no 'depths'; there is surface everywhere."

- *Common view of science*: Reliance on observational data, in contrast with philosophy and metaphysics.

- *But*: Is this an accurate view?
  - Most particle physicists will tell you quarks really exist!
  - Most biologists will tell you genes really exist!

- *Why?*
- Evidence!
- How does evidence support claims about the existence of unobservable objects?
- Why should we believe in quarks but not in poltergeists?