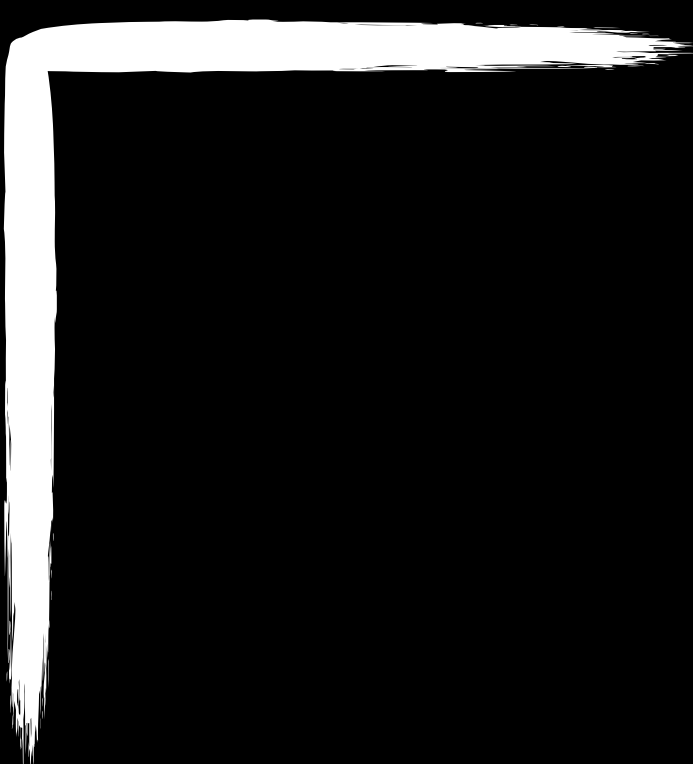
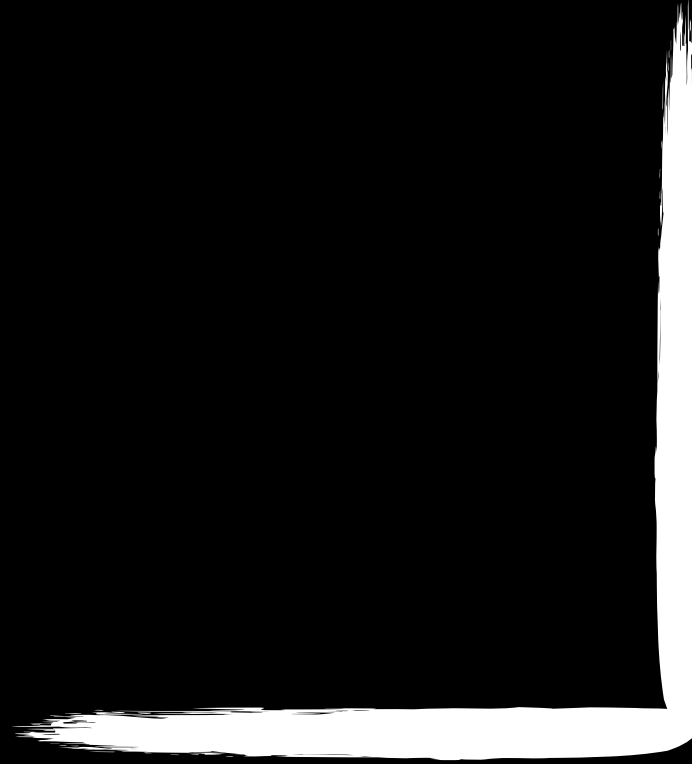




Philosophy of Physics

-

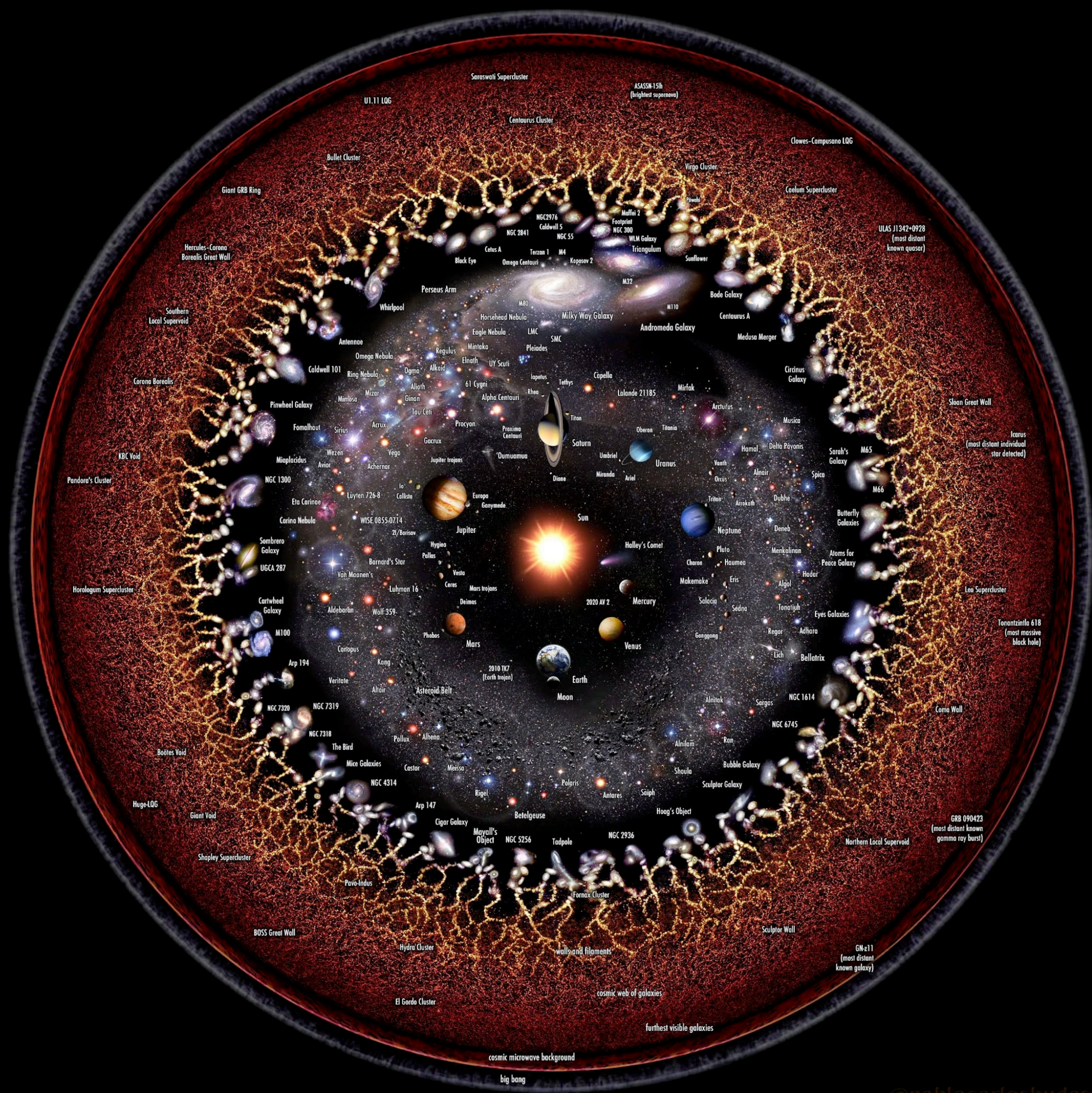
Permanence and Impermanence





In your groups, propose a
hypothesis for what is happening (5 min).

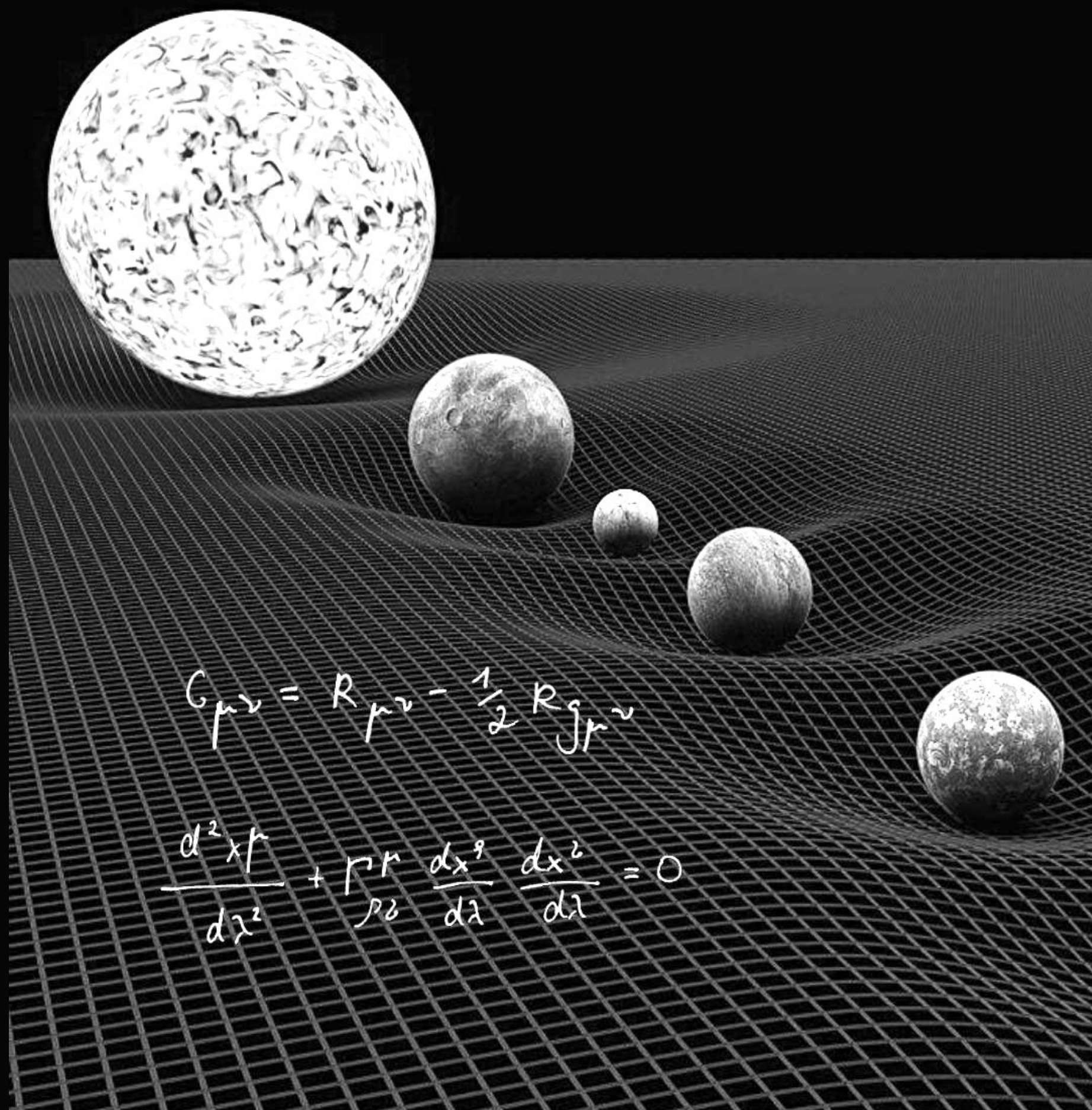
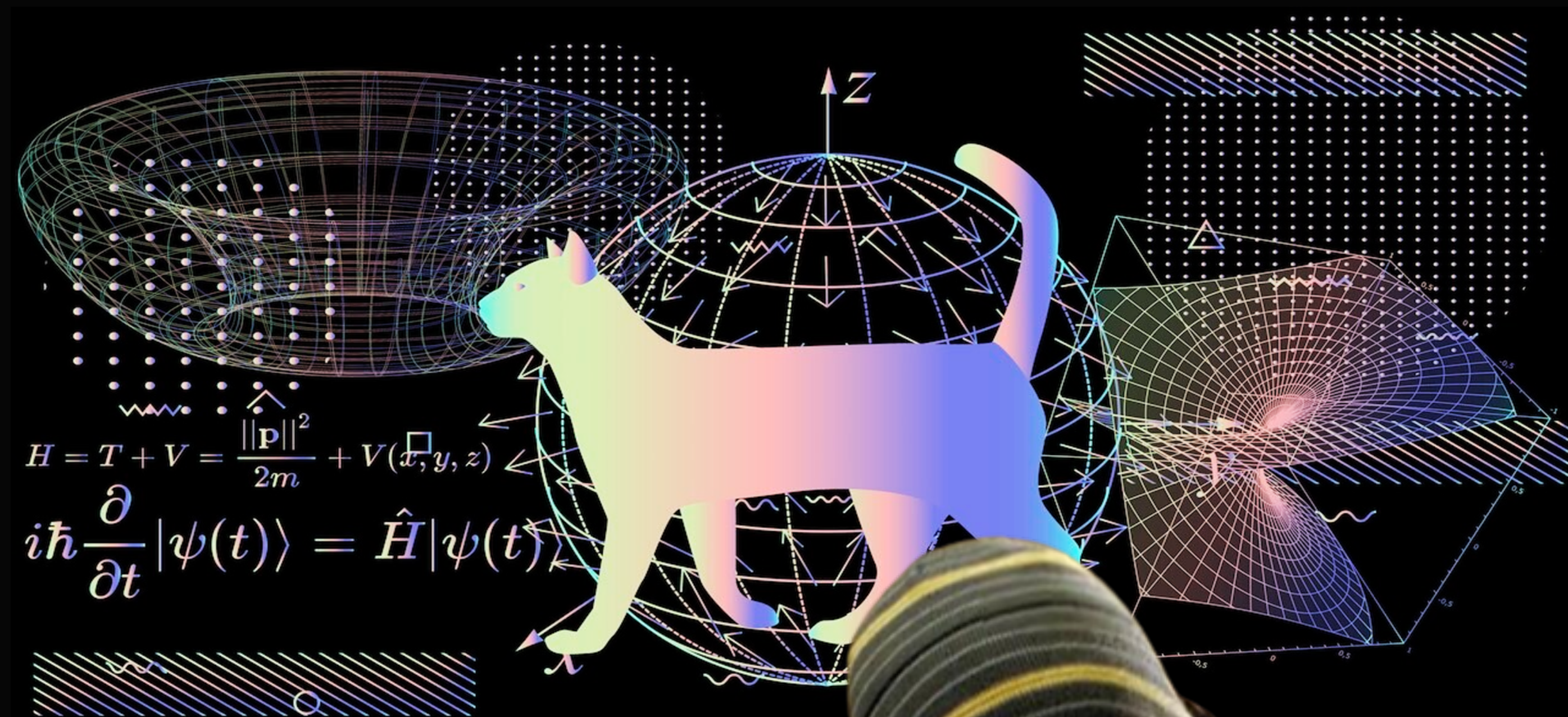
Who am I?



(Pablo Carlos Budassi)

@pablocarlosbudassi

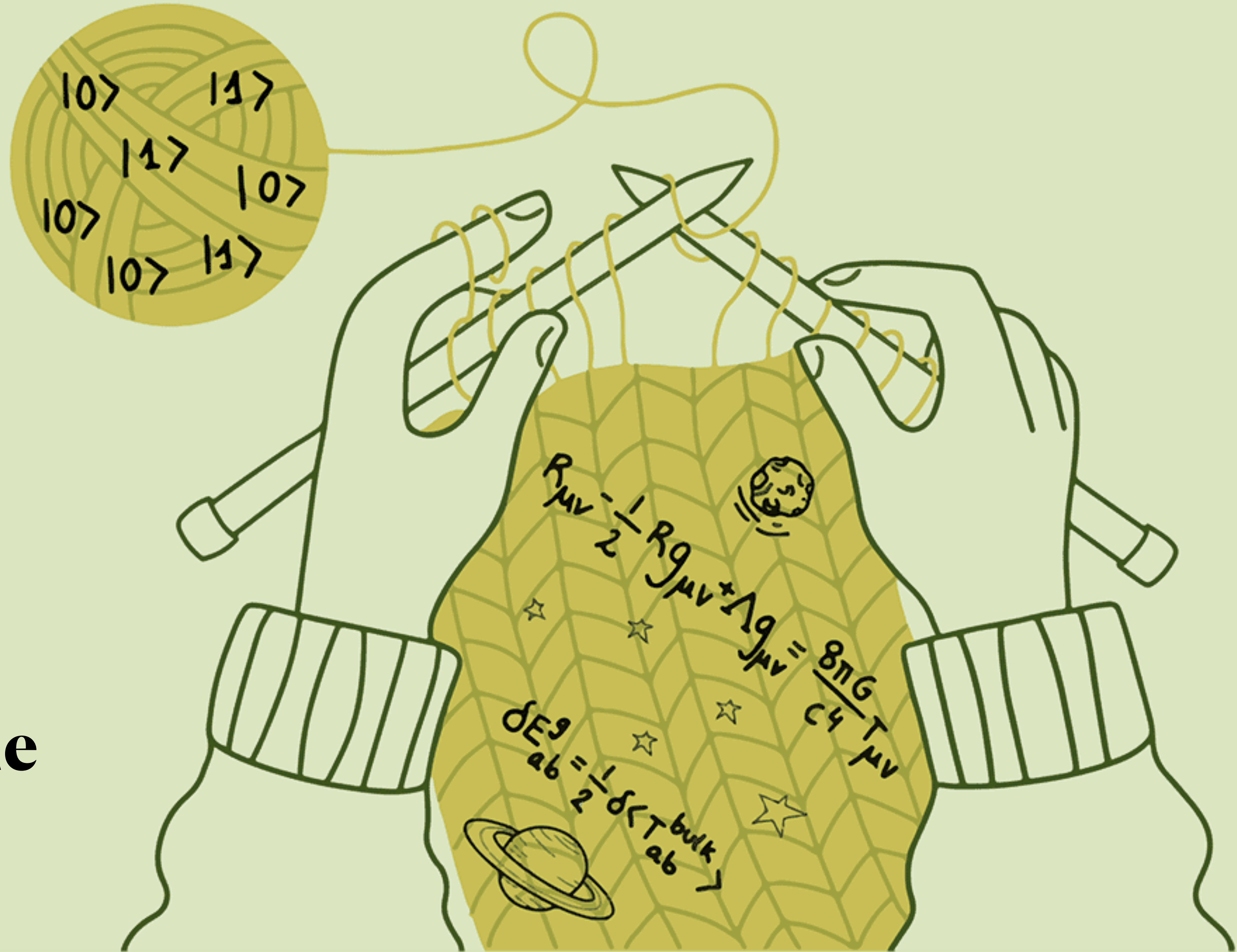
Quantum Mechanics



General Relativity



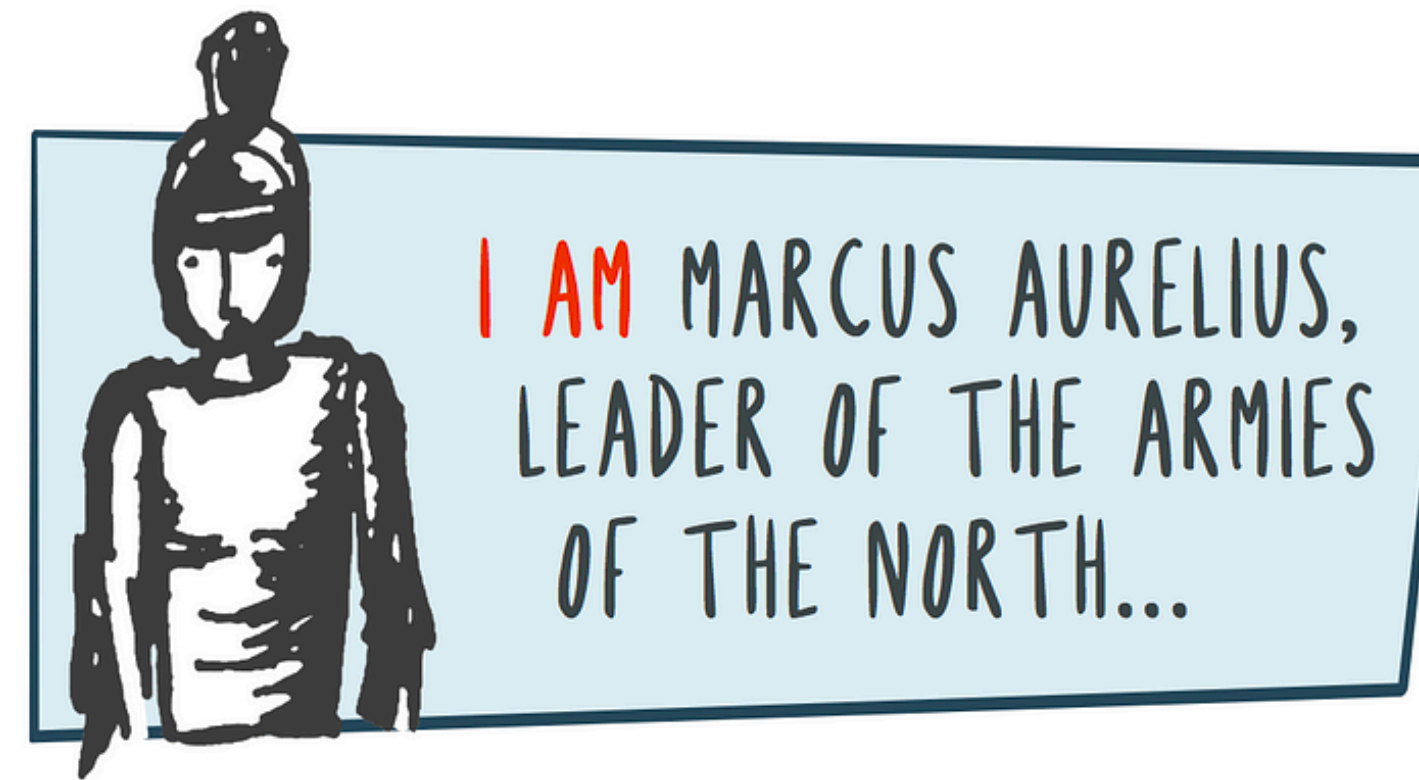
Is Spacetime Emergent?



WAYS OF INTRODUCING YOURSELF...

Who are you?

- Name
- Major
- Reason for taking this class
- Previous experience in philosophy

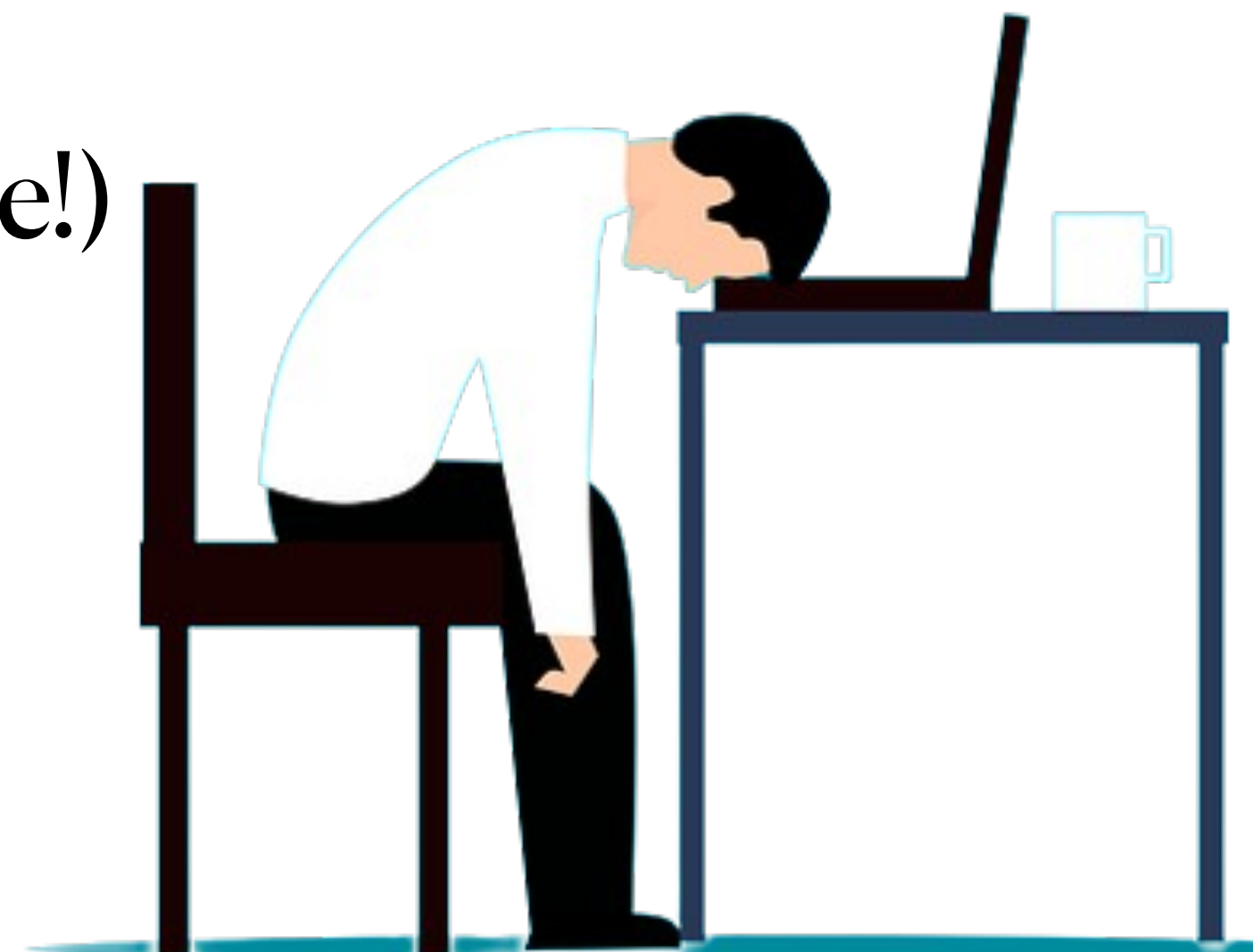


@bryanMMathers

Introduce yourself to your group. After this, each group will name one reason why folks are taking this course.

Session Structure and Expectations

- Do you have access to Athena?
- 8 sessions of 2,5hr long 😭 - 15 minute break and *possibly* finishing the session 15 mins early? 🎉
- Attending 50% of lectures is **mandatory** (if less, talk to me!)
- What to expect from a lecture



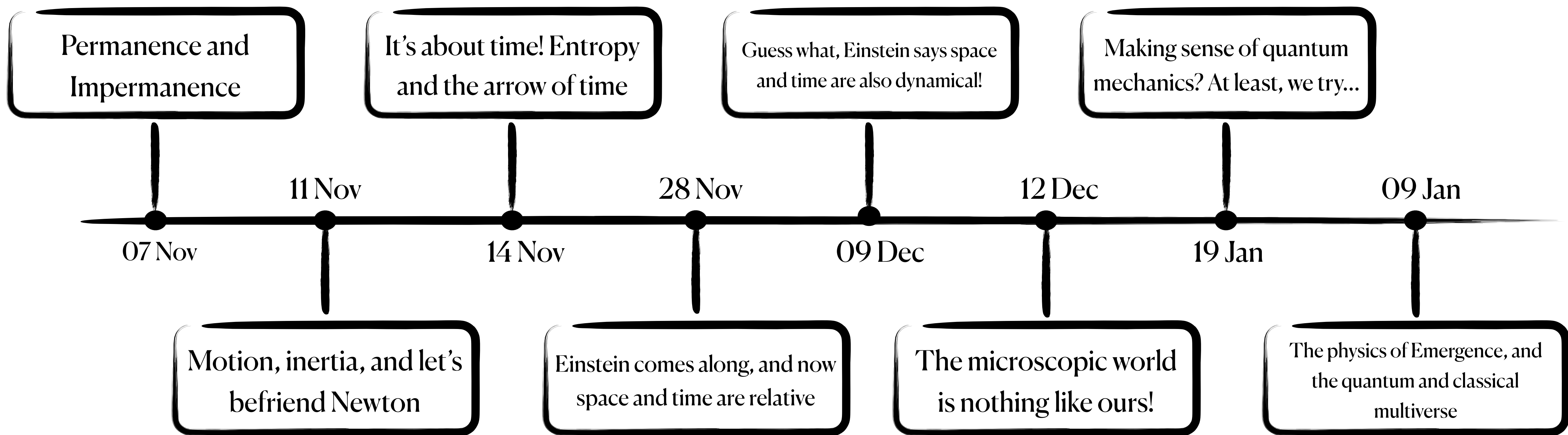
- **Absolutely expected you read the literature before the class!**
- Reading philosophy can be HARD
 - Don't be discouraged if you don't understand it all on the first reading. Try to take notes as you go
 - Revisit some, or all, of the chapters a second time to ensure that you have understood the material
- To prepare for the class discussion you should reflect on what you've read. Ask yourself:
 - Could I reconstruct the argument in the text? Do I agree/disagree with the conclusion, and why?
 - How might the proposed positions apply to a novel example?
- Come to class with at least one question you'd like to clarify/discuss



- Participation in class: one of the best ways of ‘doing philosophy’ is through discussion
- **Respect:** you may (in fact you’re encouraged to) disagree with me, the textbooks, and each other, but we will make sure that discussion stays friendly
- Literature
- Feedback at any time!

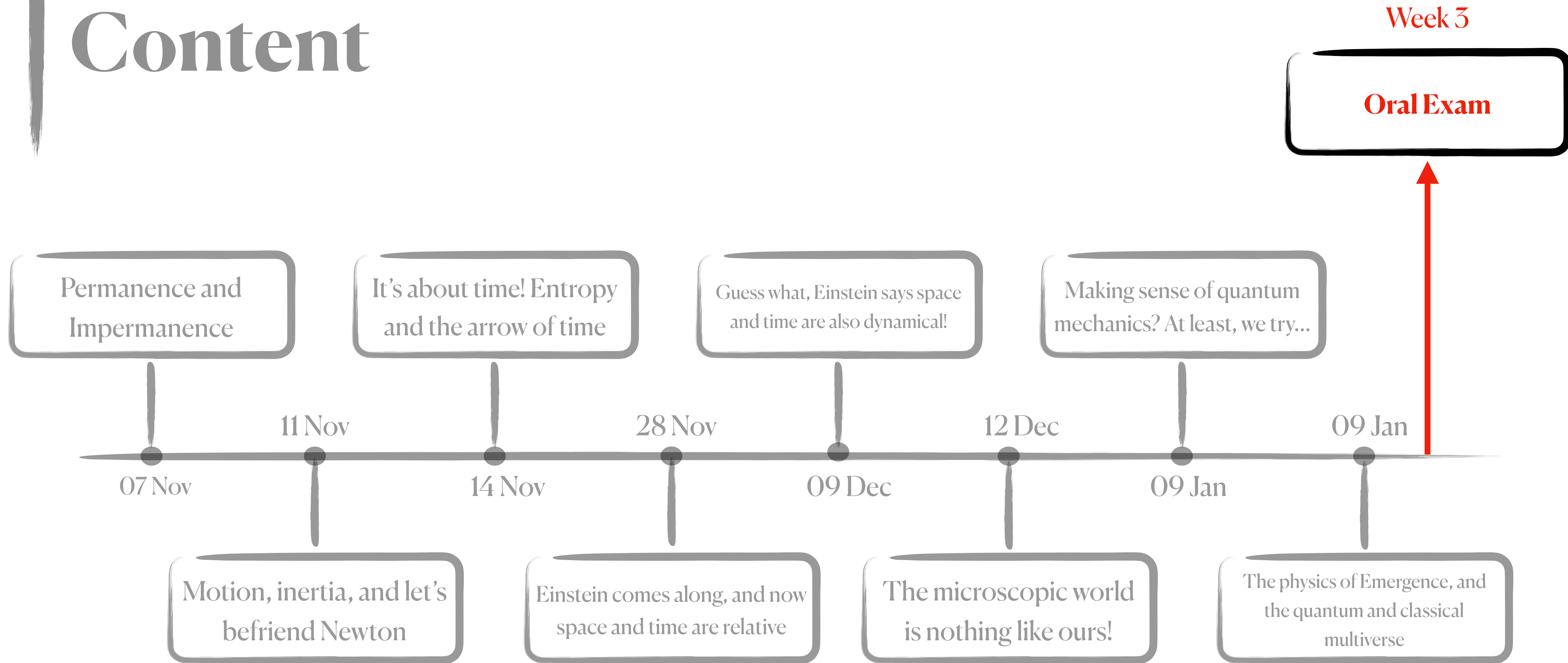


“Don’t worry, the expectations are the same as ever ... only completely different.”



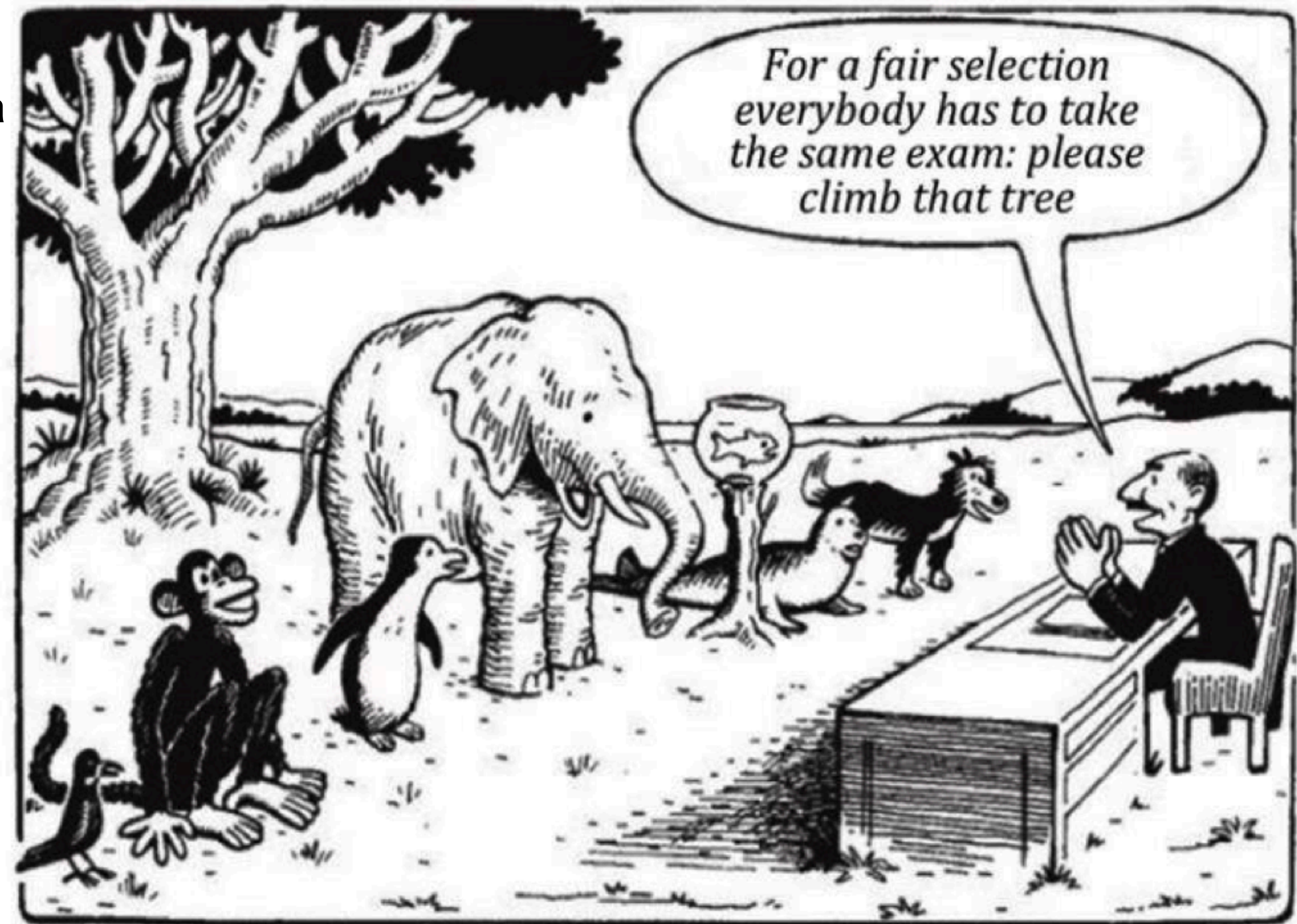
Course Content

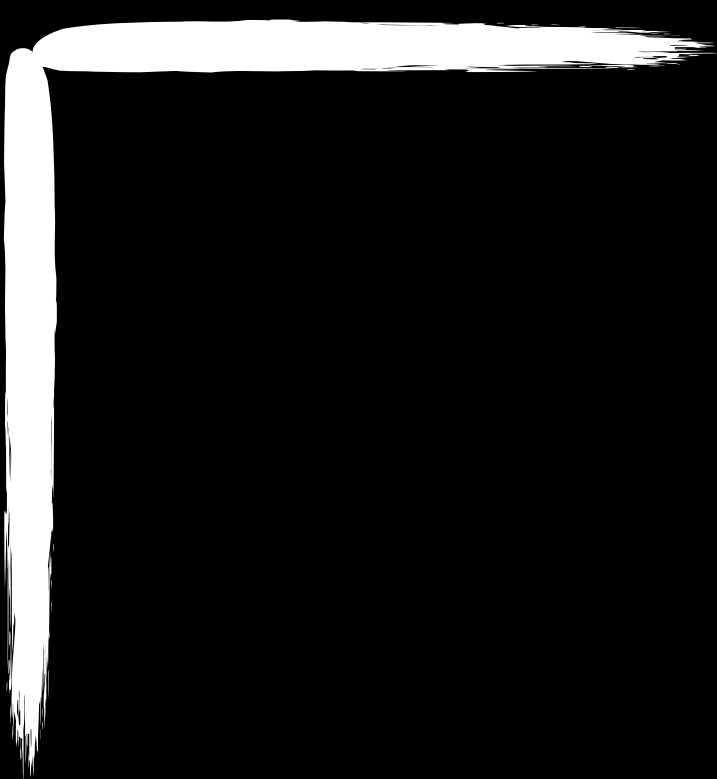
Course Content



Assessment

- There will be a **single oral exam** for this course
 - Two questions from different sessions - 10 minutes for each
 - Questions are picked up at random
 - The questions will have been discussed in class
- More information about grading criteria later, but
 - Conversational format
 - Less focus on details, more focus on how to think about the questions





Questions?

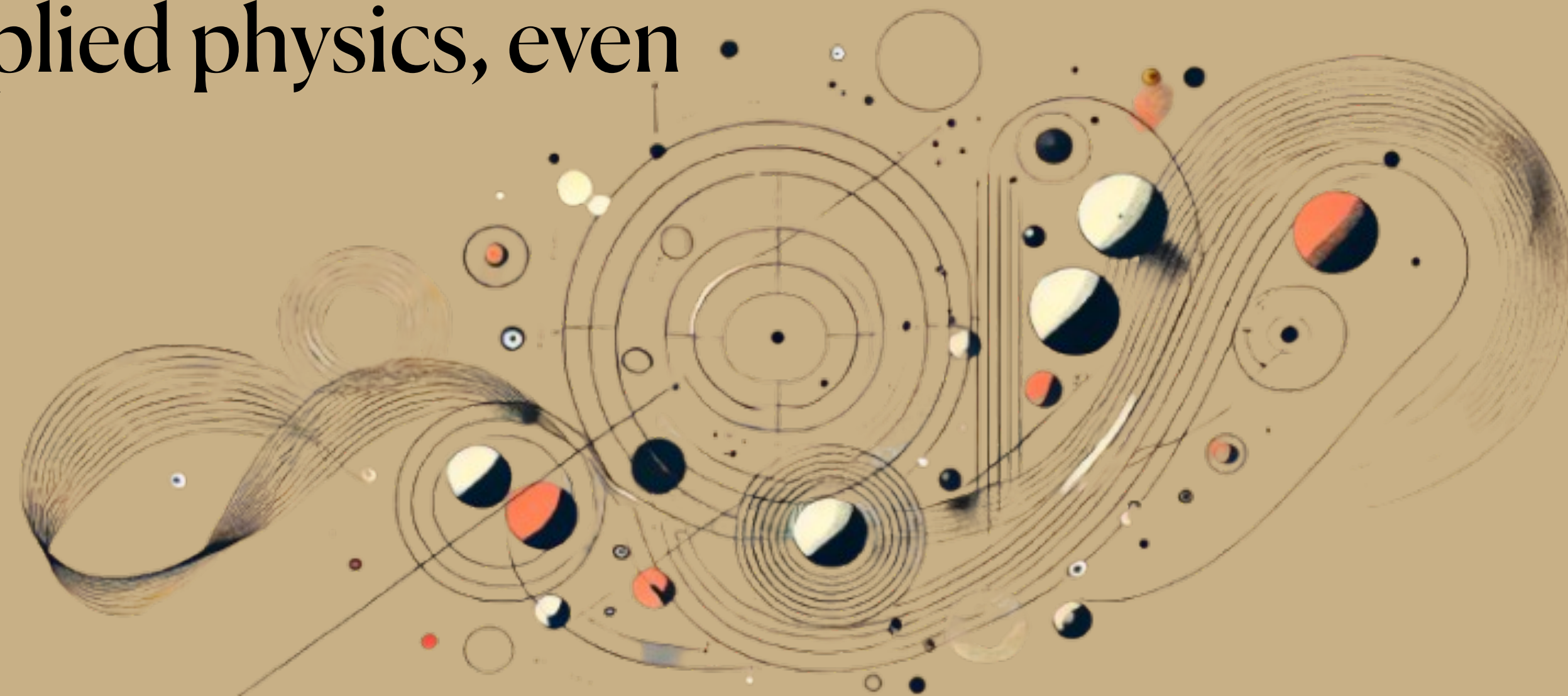


What is Physics?

(In your groups - 5 min)

What is Physics?

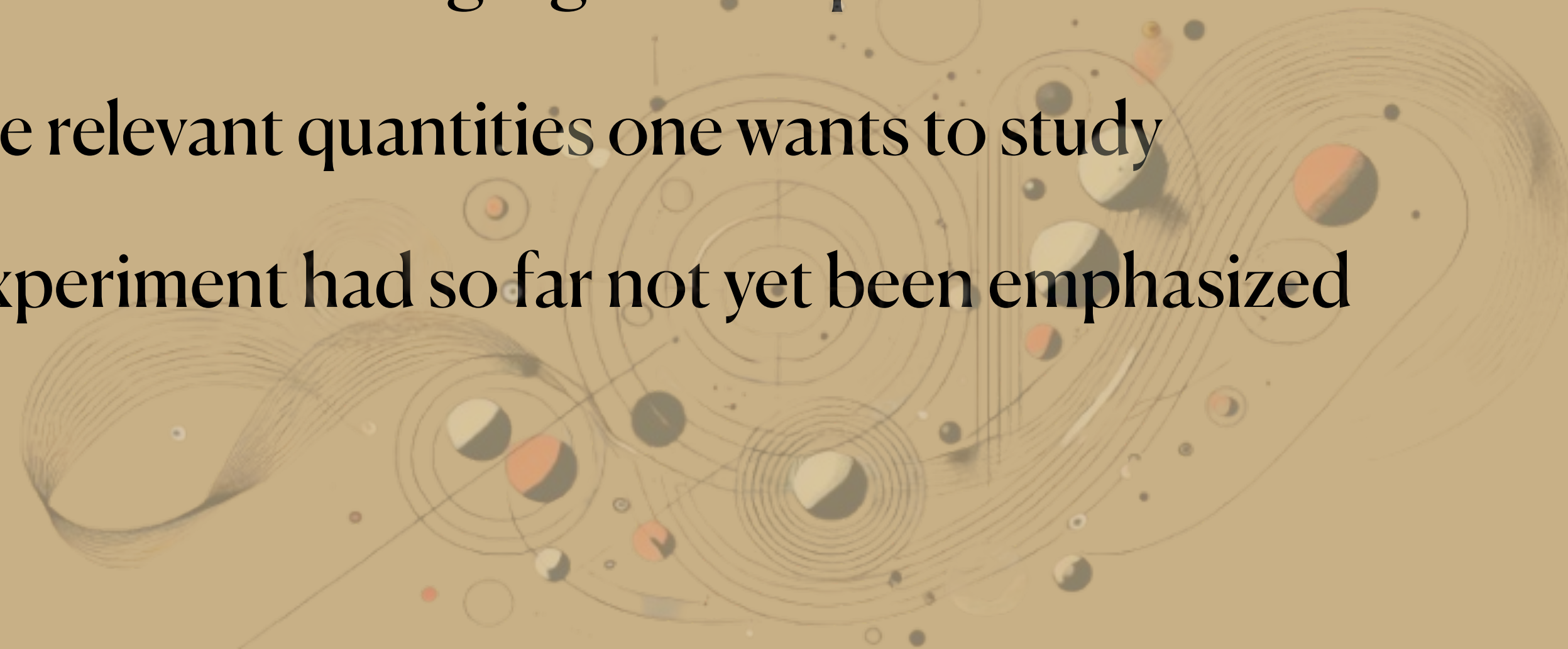
- **Regularities** in nature (but so in other disciplines)
- Determines **fundamental laws** of nature? (Are we *reductionists*?)
- Interested only in **general principles**, other disciplines have contingencies (but what about applied physics, even fundamental physics?)



What is Physics?

Aristotle - from knowledge of nature as a whole way beyond what today is considered physics
to **Galileo's** - using *mathematics* and *experiment*

- Astronomy had used mathematics extensively since antiquity: i) The Ptolemaic planetary model was a complex system of moving circles; ii) then Kepler's laws of planetary motion introduced ellipses and mathematical expressions relating e.g. orbital period and size
- Devising simple experiments to isolate the relevant quantities one wants to study (*spherical cow philosophy*). The role of experiment had so far not yet been emphasized until Galileo used it systematically



What is Philosophy?

“Philosophy deals with questions that the sciences cannot yet, or **ever**, address, and why that is the case.”

Q: What would be examples of such questions?

Q: Examples that used to be as such and became scientific?



Natural Philosophy

Modern science began to take shape in the 16th Century under the heading of 'natural philosophy'.

During the Scientific Revolution (1543 - c.1700), natural philosophers developed systemic knowledge about the world by emphasising the importance of **experiments** and the development of **novel instruments**:

- Telescopes, vacuum chambers, dissections, etc.

And they developed theories that we (to some extent) still believe today:

- Heliocentric, Newton's laws of mechanics, etc.



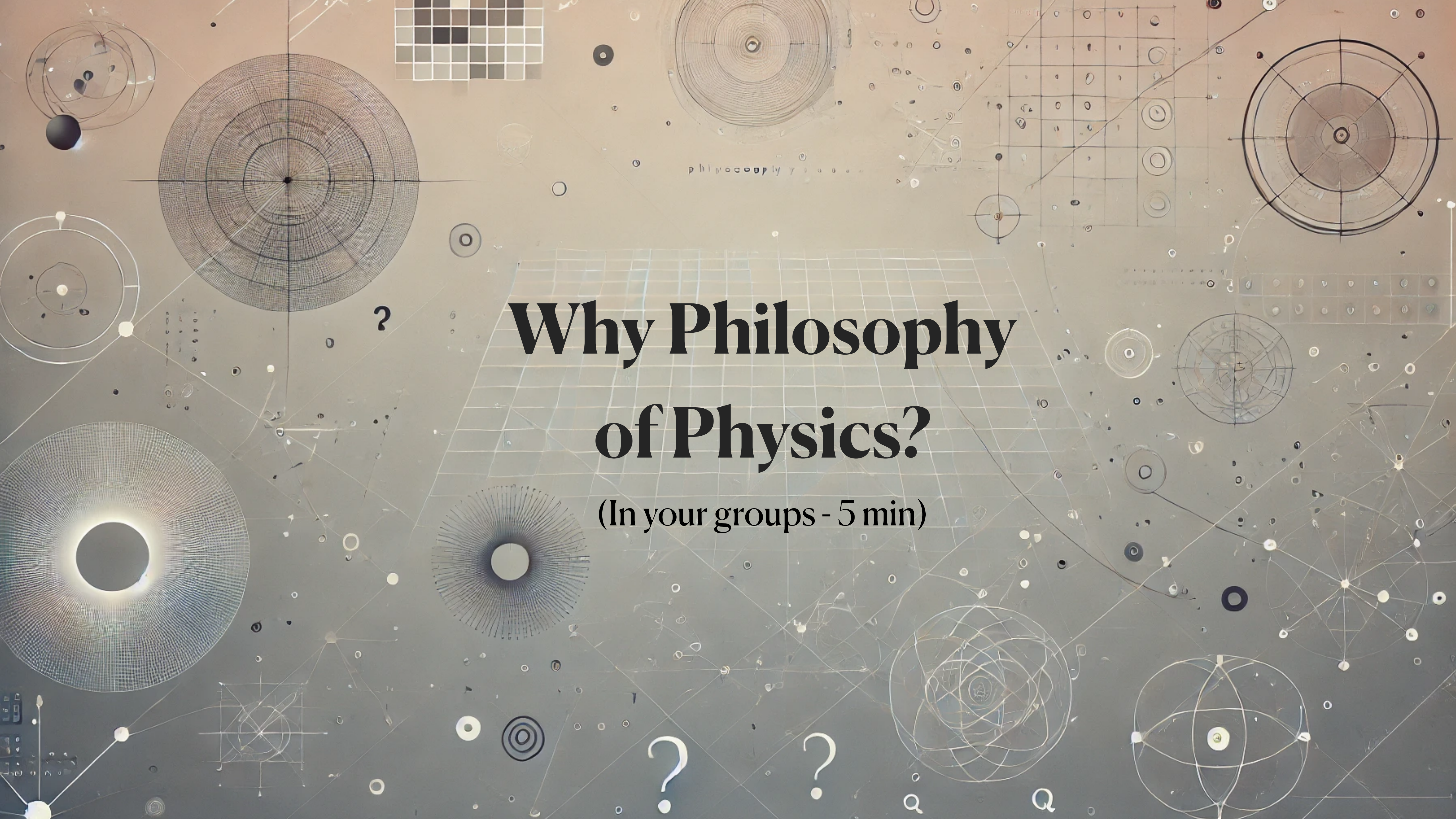
The beginning of Philosophy of Science

The natural philosophers in this period (e.g. Galileo, Bacon, Descartes, Newton, du Châtelet, etc.) spent time experimenting, theorizing, measuring, and so on.

But they also spent time reflecting on their methods, asking themselves why they thought engaging in these practices was the best way to proceed in learning about the world.

Of course they didn't distinguish between 'scientific' and 'philosophical' questions: it may be more useful to see their thought as part of a complete package.





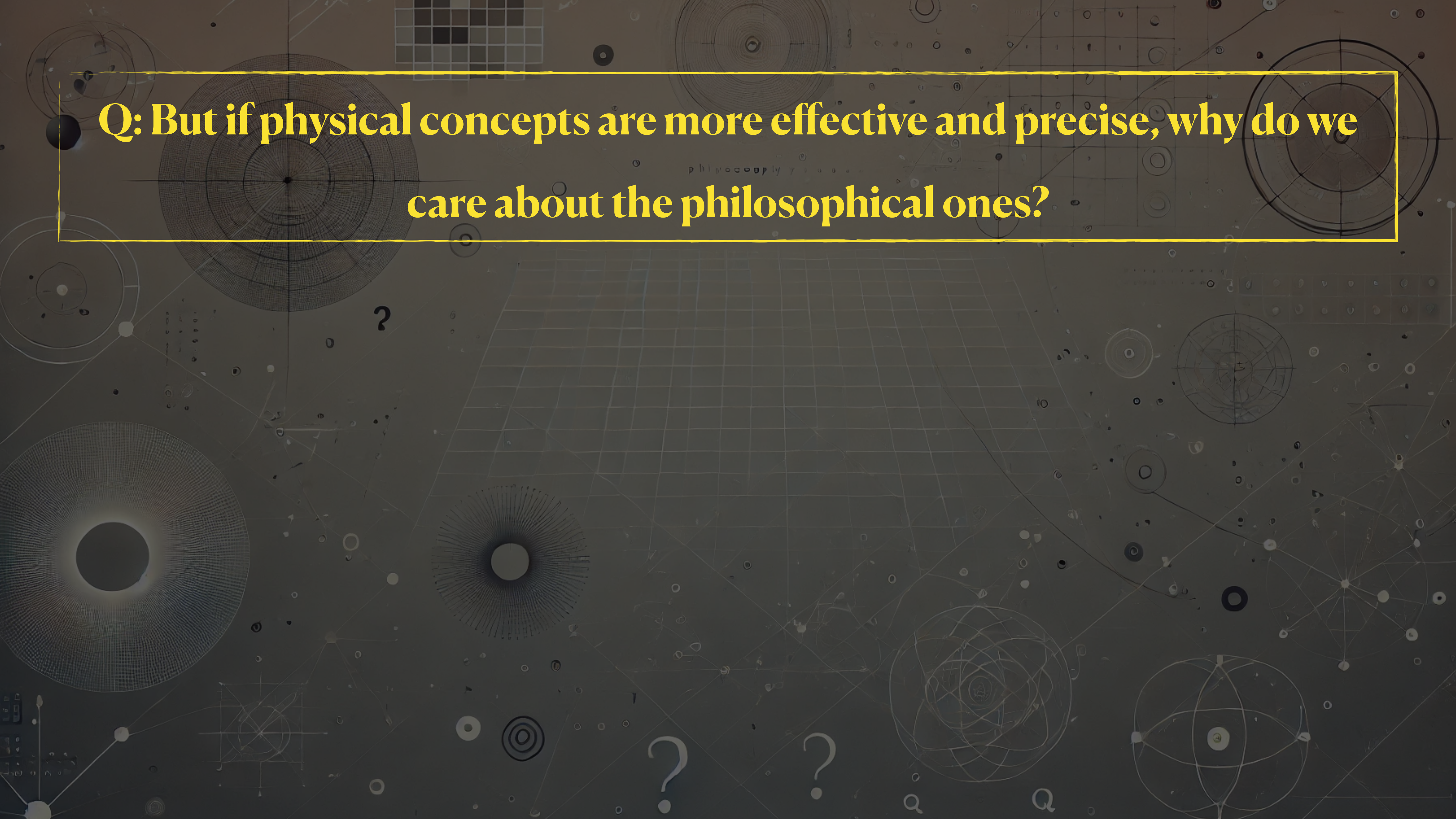
Why Philosophy of Physics?

(In your groups - 5 min)

Why Philosophy of Physics?

- Philosophical clarity has helped move physics forward given there is **no clear separation between the concrete, predictive aspects of physics and its conceptual foundations**: e.g. what is time?
- To consider the methods of science without any particular example in mind can be deceiving
- To get the best understanding of what the world is like, we need to be scientifically literate – **philosophy of physics instructs us how to do metaphysics**
- Because **our data underdetermines our theories**, so it becomes important to use a more conceptual approach to evaluate the features of the different theories available

- Philosophy of physics applies philosophical concepts to physical concepts
 - * Physical concepts are mostly developed based on intuitions but then typically have a precise definition within the theory in which they are used (?). It often involves
 - ★ A mathematical definition within the theoretical formalism
 - ★ But also a physical aspect that latches on the observational data
 - ♦ E.g.: mass, acceleration, velocity
- Philosophical concepts, however, lack a precise mathematical definition, and they draw their significance from their roots in intuition and their philosophical conceptualization
 - * E.g. ontology, reality, causality, determinism, etc

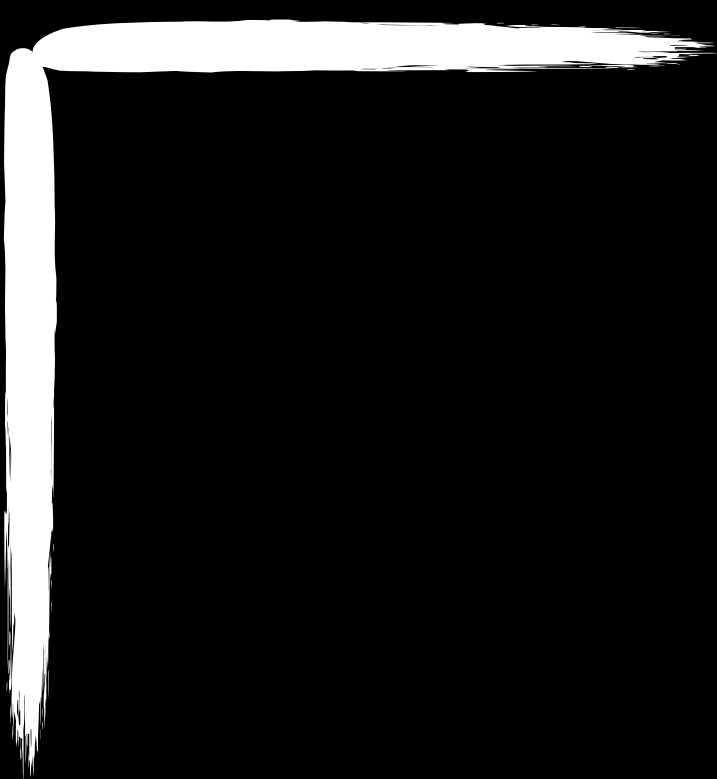
The background is a dark, textured collage of various scientific and philosophical diagrams. It includes several circular diagrams with concentric circles and radial lines, resembling atomic models or celestial maps. There are also rectangular grids, some with small circles or dots, and various geometric shapes like triangles and lines. The overall aesthetic is that of a historical or scientific manuscript. A yellow rectangular box is superimposed on the upper left, containing the text.

Q: But if physical concepts are more effective and precise, why do we care about the philosophical ones?

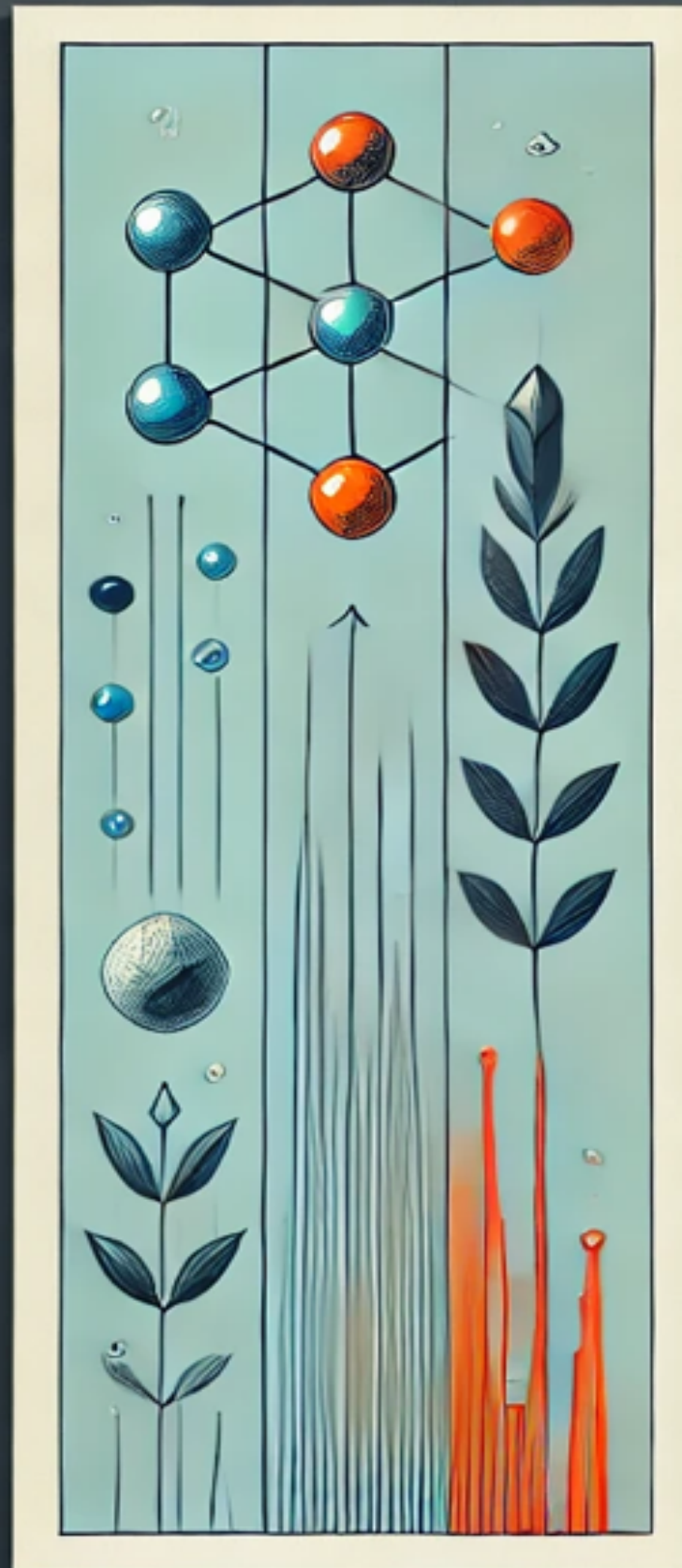
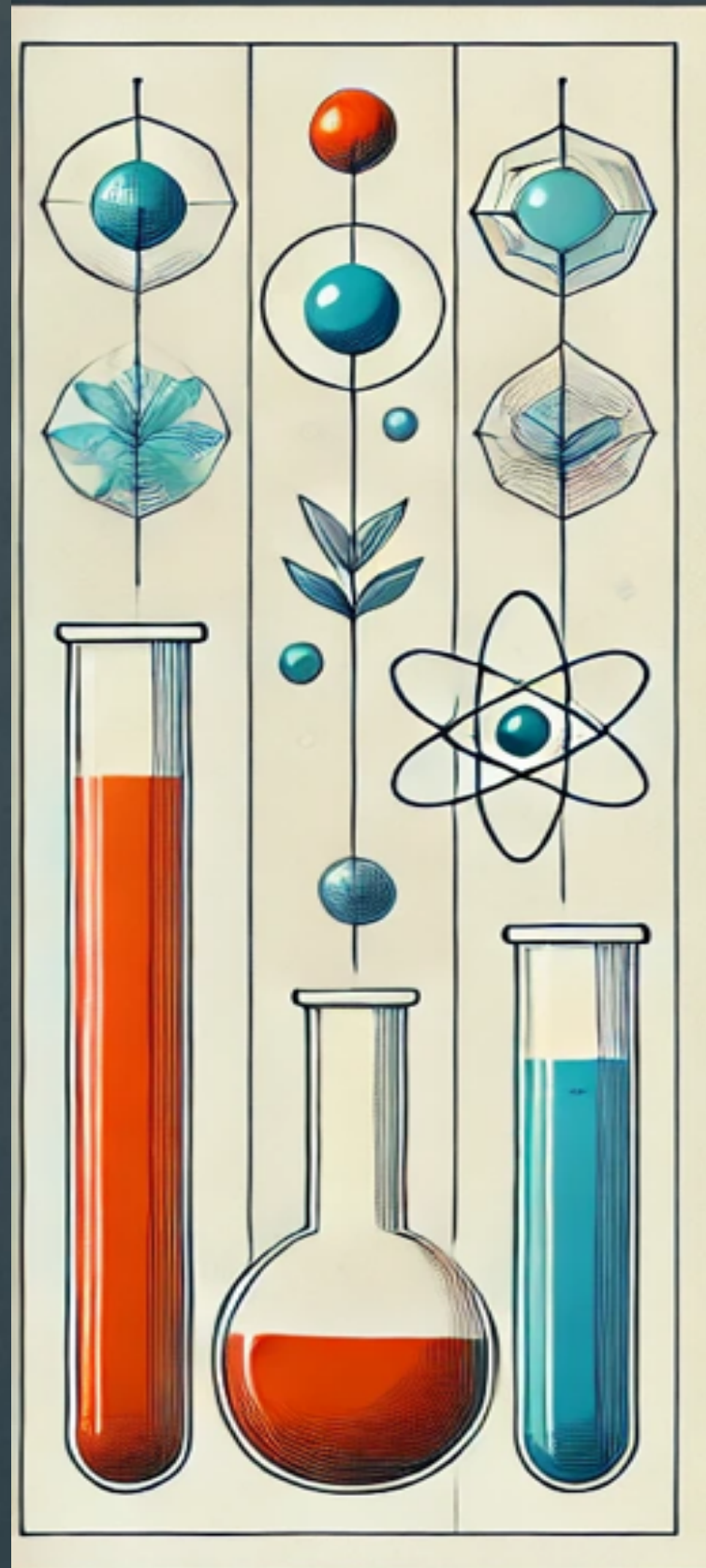
Q: But if physical concepts are more effective and precise, why do we care about the philosophical ones?

It has always been the case that when fundamental physics undergoes a revolution, mostly induced by a shift in the theoretical framework, that leads to deep conceptual change, where initially the new entities of the new theory are not fully understood.

We will see, over and over again throughout this course, that by asking deeper and deeper questions in the context of a physical theory we can arrive at situations that only deep philosophical inquiry can help us understand, especially given that the physical theories quickly become intractable when applied to complex systems such as us, humans, and the whole universe.

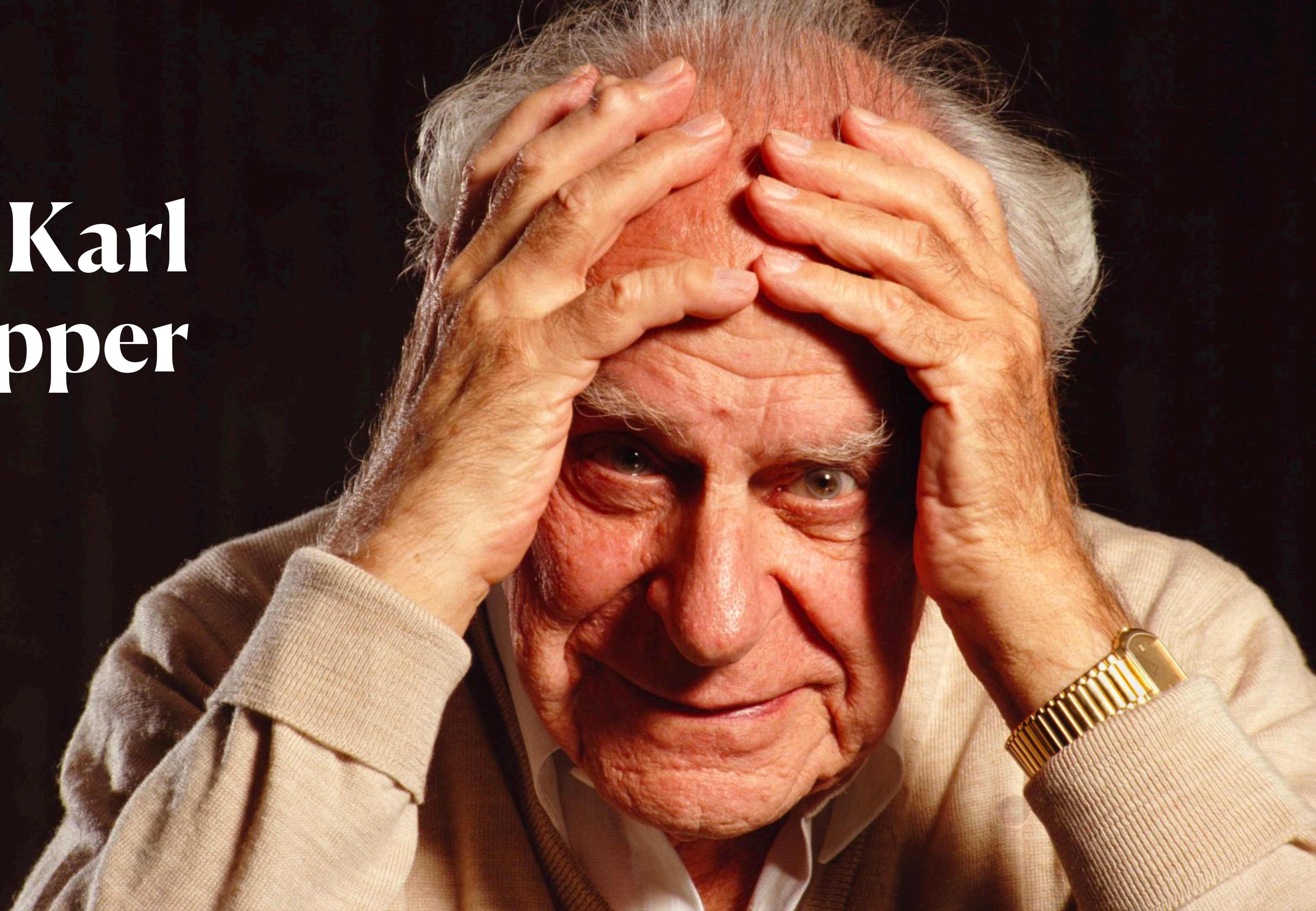


Questions?



How does Science work?

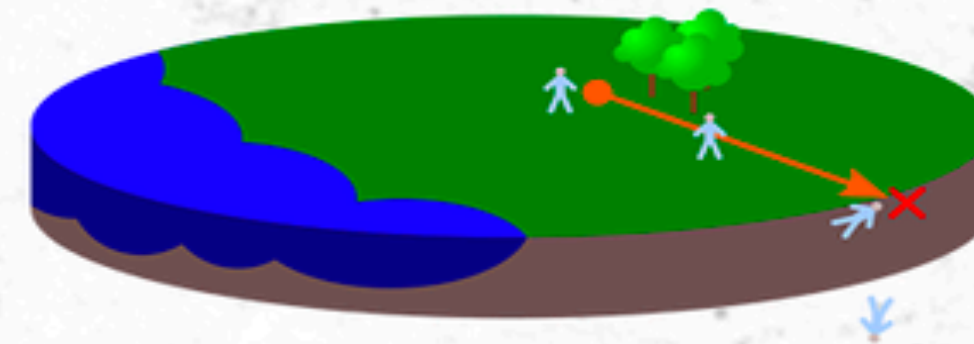
Karl Popper





Science

Pseudoscience



Popper claims that scientists are actually worried about **seeking negative evidence against scientific hypotheses**.

However, his claim was not that scientists should seek strict falsification. He articulated that the best science is characterized by **framing hypotheses that are highly risky**, and therefore easy to test, and when they fail these tests (as eventually they will), then new risky hypotheses should be framed. **Thus, he held that the business of experiment is to seek disconfirmation.**

Popper's claim about falsifiability may be treated as a **description** of the attitudes of scientists or a **prescription** about what attitudes they should have!

Q: Is that the case?



1. How could you falsify your hypothesis? (5 min)

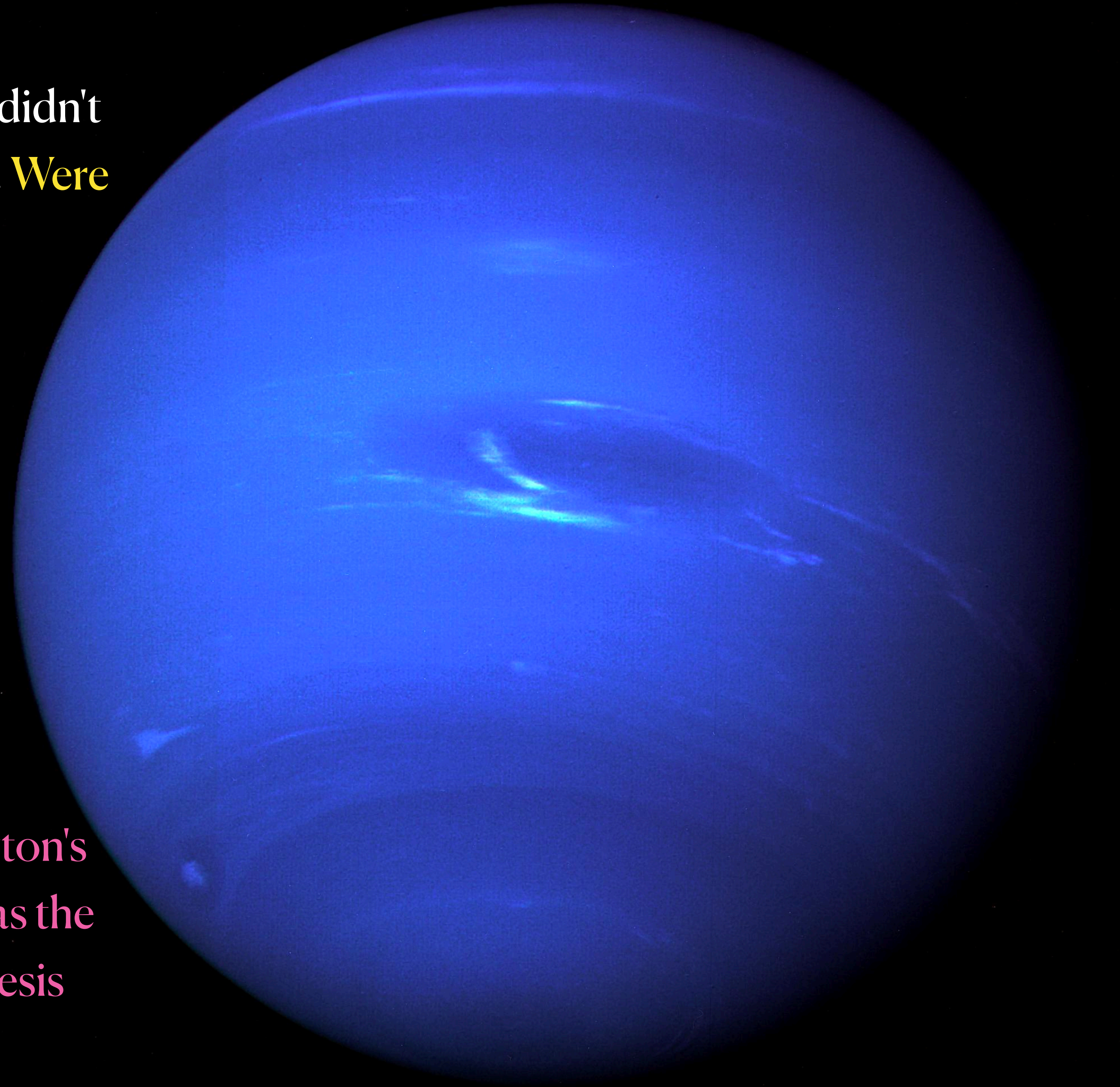
The Discovery of Neptune: A Case Study -

Early 1900s, astronomers observed that Uranus's orbit didn't exactly match the predictions made by Newton's gravity. **Were they incorrect or incomplete?**

Instead of questioning Newton's laws, Adams and Le Verrier hypothesised: **What if there was another, as-yet-undiscovered planet whose gravitational pull was affecting Uranus's orbit?**

They predicted where this hypothetical planet should be. When astronomers pointed their telescopes to the predicted location, they did find **Neptune**.

From a falsificationist perspective, **the point is that Newton's laws themselves were never strictly "on trial"; rather, it was the entire system of Newton's laws plus the auxiliary hypothesis about Uranus that faced empirical testing.**

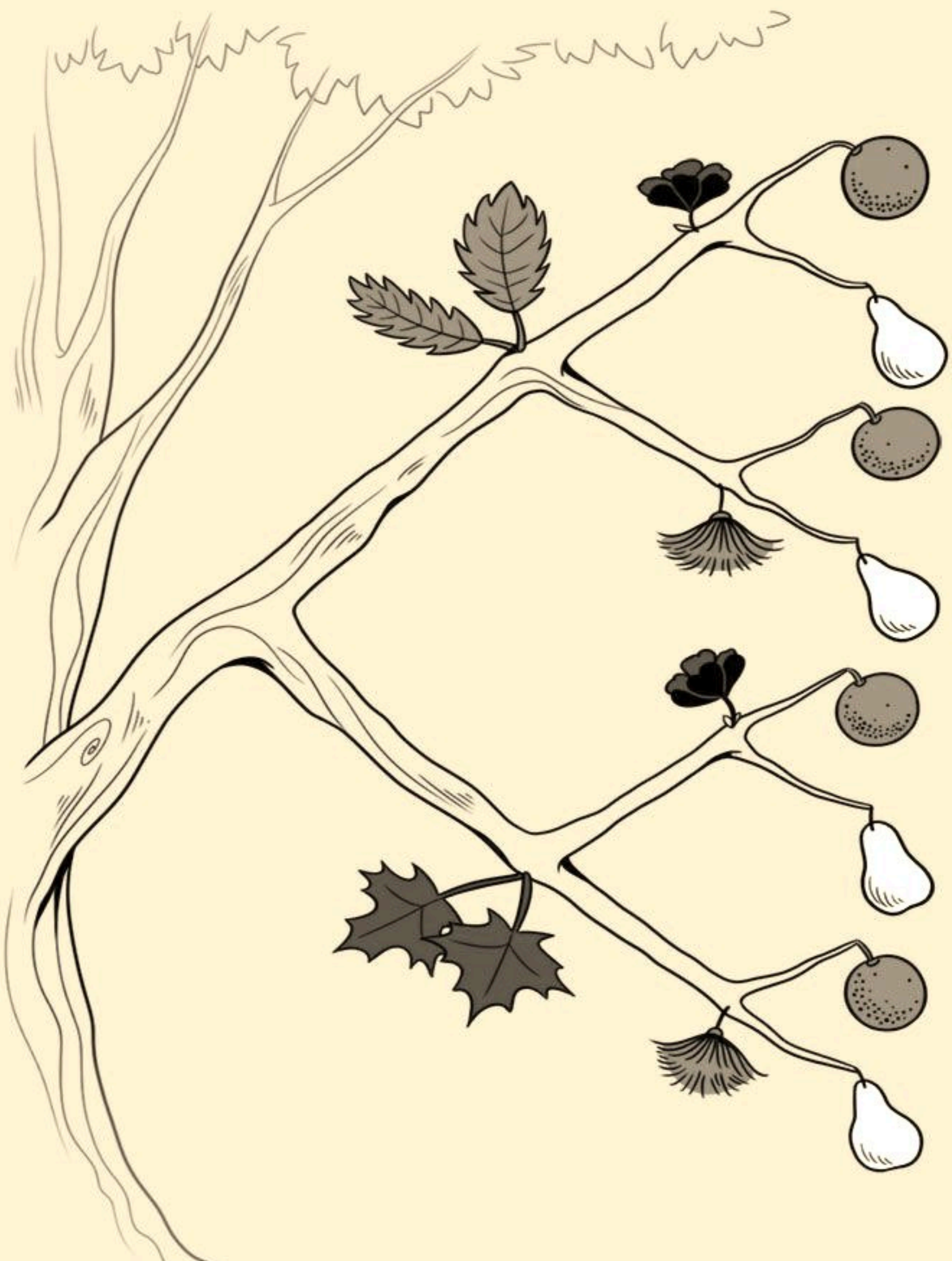




1. How could you falsify your hypothesis? (5 min)
2. What are the auxiliary hypotheses that could be wrong instead of the main hypothesis? (5 min)

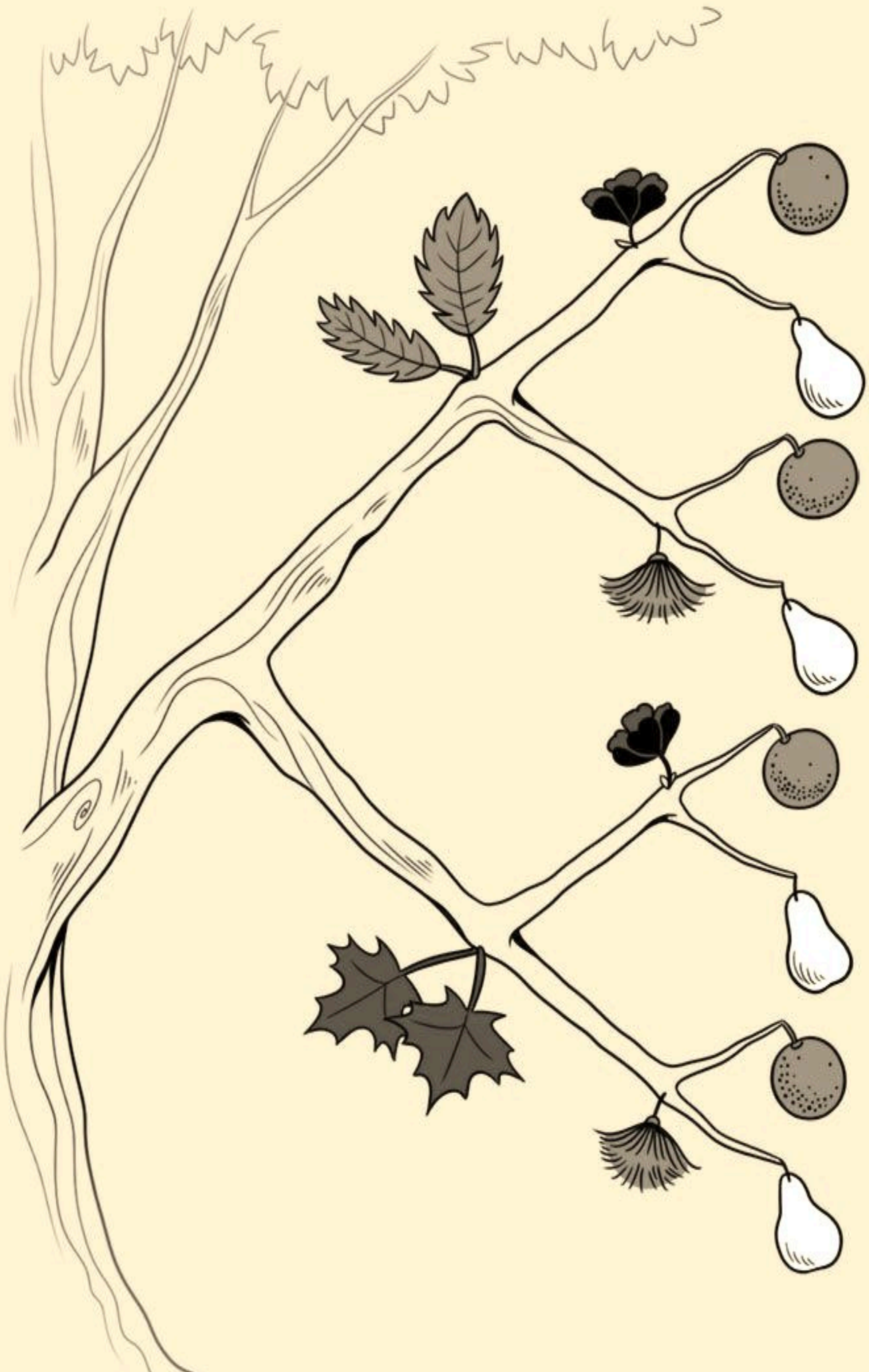
As we are not always fully aware of all possible auxiliary hypotheses,
scientific laws can neither ~~completely established~~ by available
evidence, nor ~~conclusively falsified~~ by a finite body of evidence.

Underdetermination



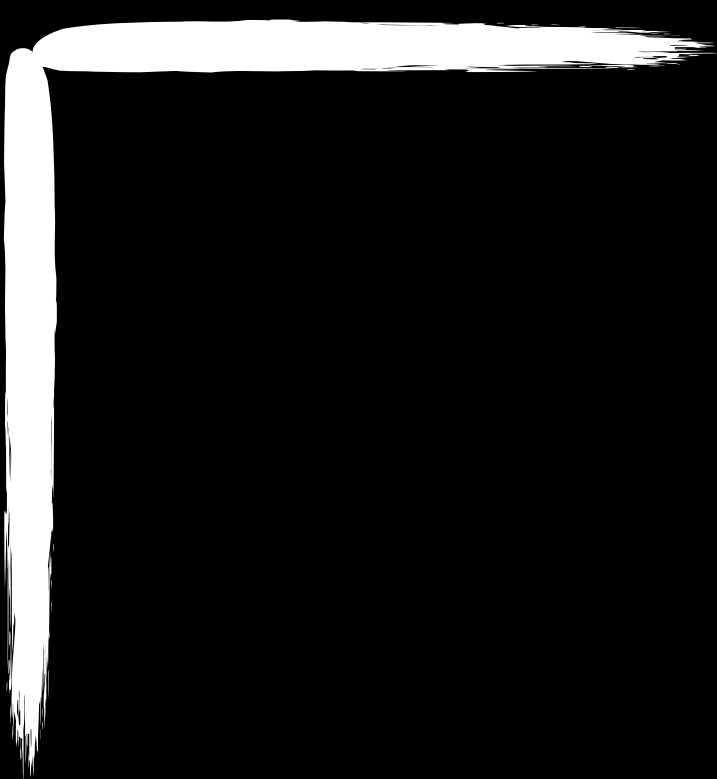
As negative tests can be due to an auxiliary hypothesis, positive tests might reflect compensating mistakes in two or more hypotheses. Thus, **it seems unavoidable to conclude that there is underdetermination of theory by observation.**

Since typically there is a whole array of hypotheses at play during any empirical test, **any negative result can trigger different scientists to change any possible combination of them to make the framework empirically adequate again.** This seems rather arbitrary and far away from our naïve understanding of science.



If empirical data alone tests theory, and if it doesn't point to where the theory needs to be changed, then over time **we would expect theories to proliferate**, *but that doesn't seem quite to be the case, especially in the natural sciences.*

The problem of empirically equivalent but logically incompatible theories becomes especially serious as science becomes more theoretical.



Questions?

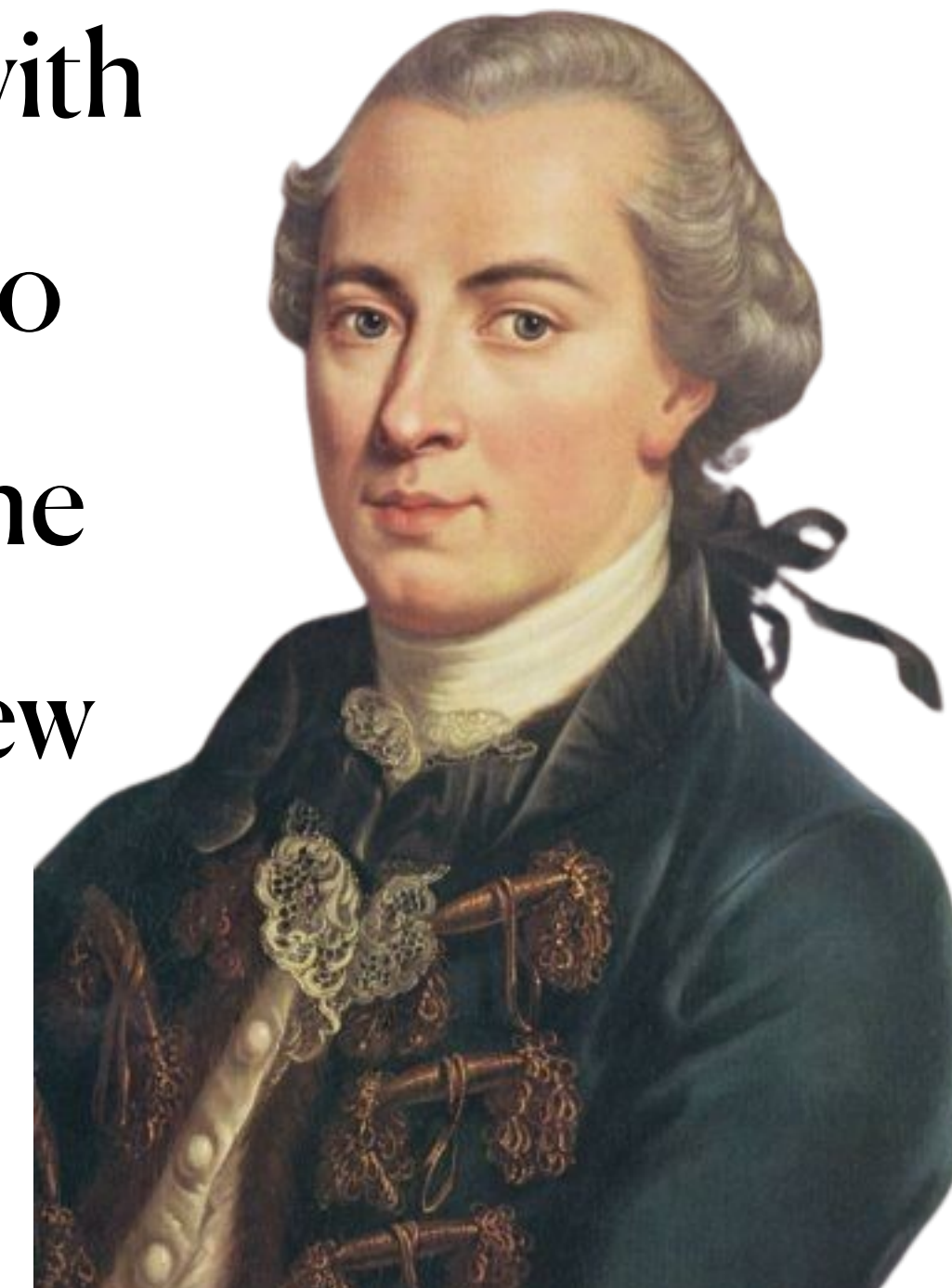


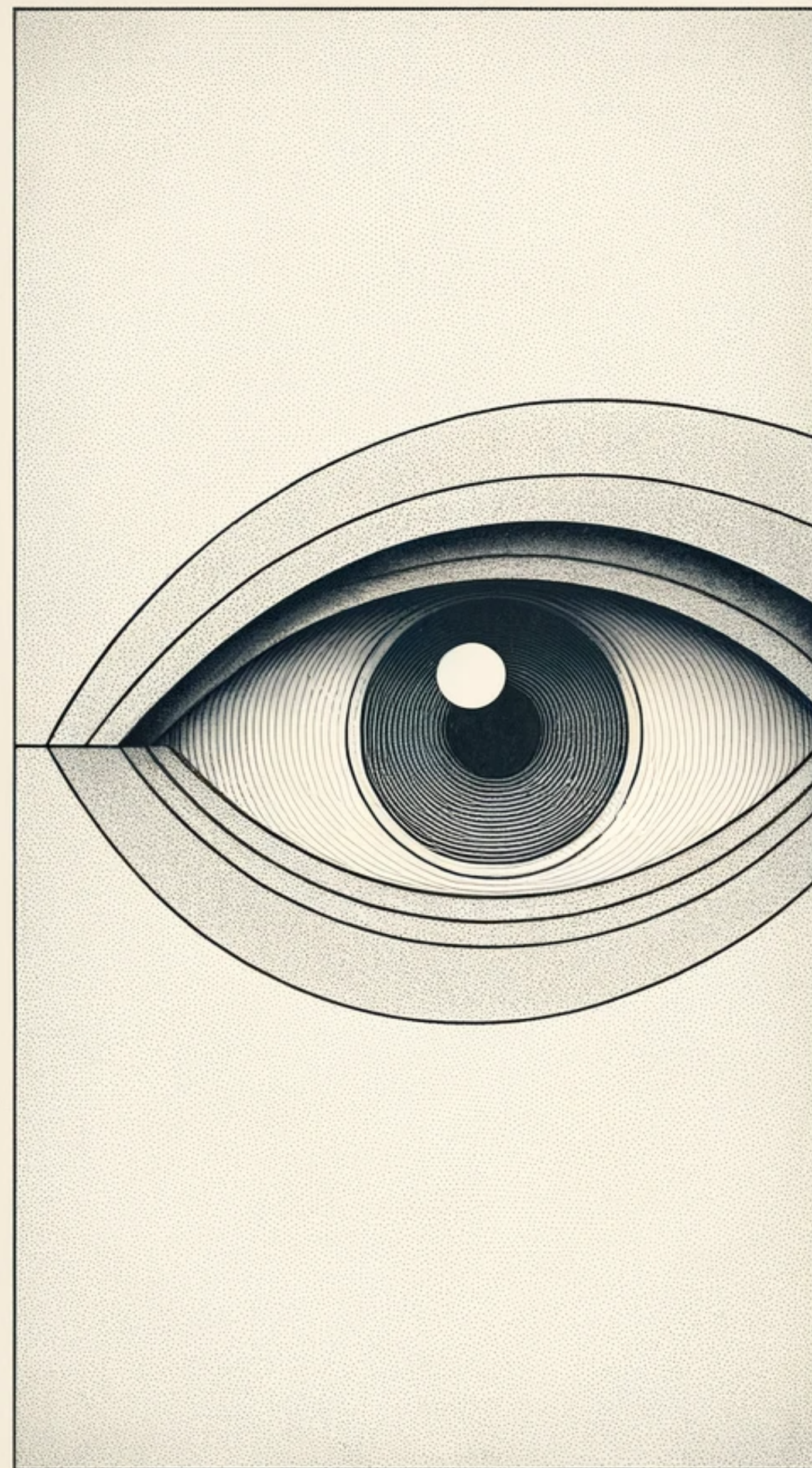
**Q: Is science supposed to tell us how or why
things are the way they are?**

It didn't take long for people, like Berkeley, to realize the difficulty of the problem and to shift perspective to treat physical theories not as a knowledge of reality, but as a set of **instruments**.



On the other camp, **scientific realism** was being born with Leibniz and Kant, who argue that Newton's laws were so predictive that they couldn't be shorter than truth. At the same time, both had to resort to rationalism as they knew that experience alone couldn't ever establish **the laws necessity let alone their universality**.



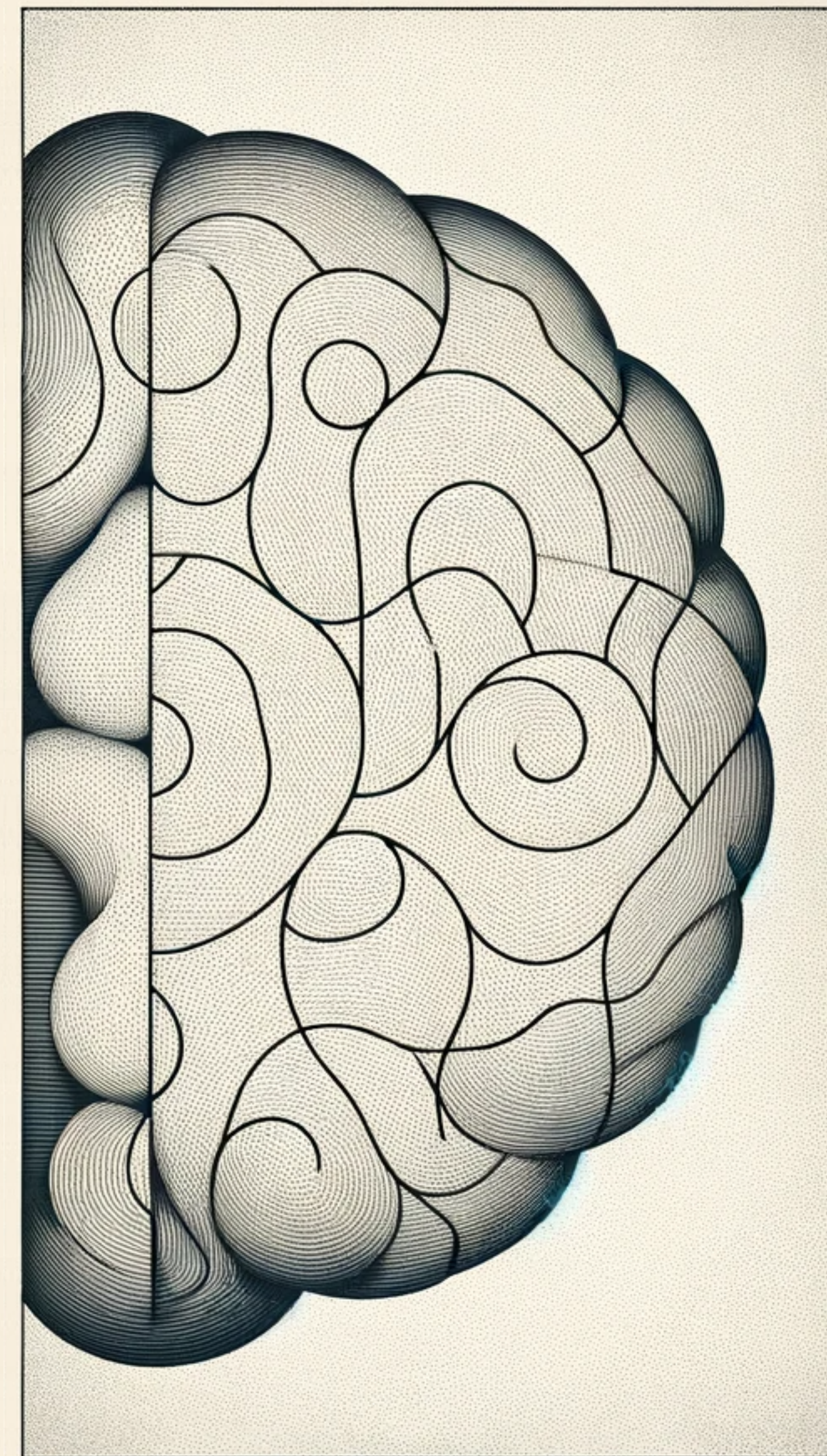


Two main currents of epistemology:

Empiricism: **all** of our beliefs about the nature of things are justified by experience, observation, the collection of data, and experiments

Rationalism: *at least some* (usually central, important) of our beliefs about the nature of things are justified in some other way

**Q: Who identifies as a rationalist?
Who identifies as an empiricist? Why?**



Instrumentalism

Scientific theories are useful instruments, tools we employ for organizing our experience, but not literal claims about the world that are either true or false.



Scientific Realism

Do we **trust** in science? If so, does that mean that scientific theories are **true**? Does it mean that the theoretical terms contained in our scientific theories refer to ***real*** unobservable aspects of the world?



Theoretical Terms

Challenge the **empiricist epistemology**

Seem necessary for unification of theories

Have **methodological value** (e.g. Einstein trying to define simultaneity)

**Q: Is knowledge ultimately justified by
our experience through our senses?**

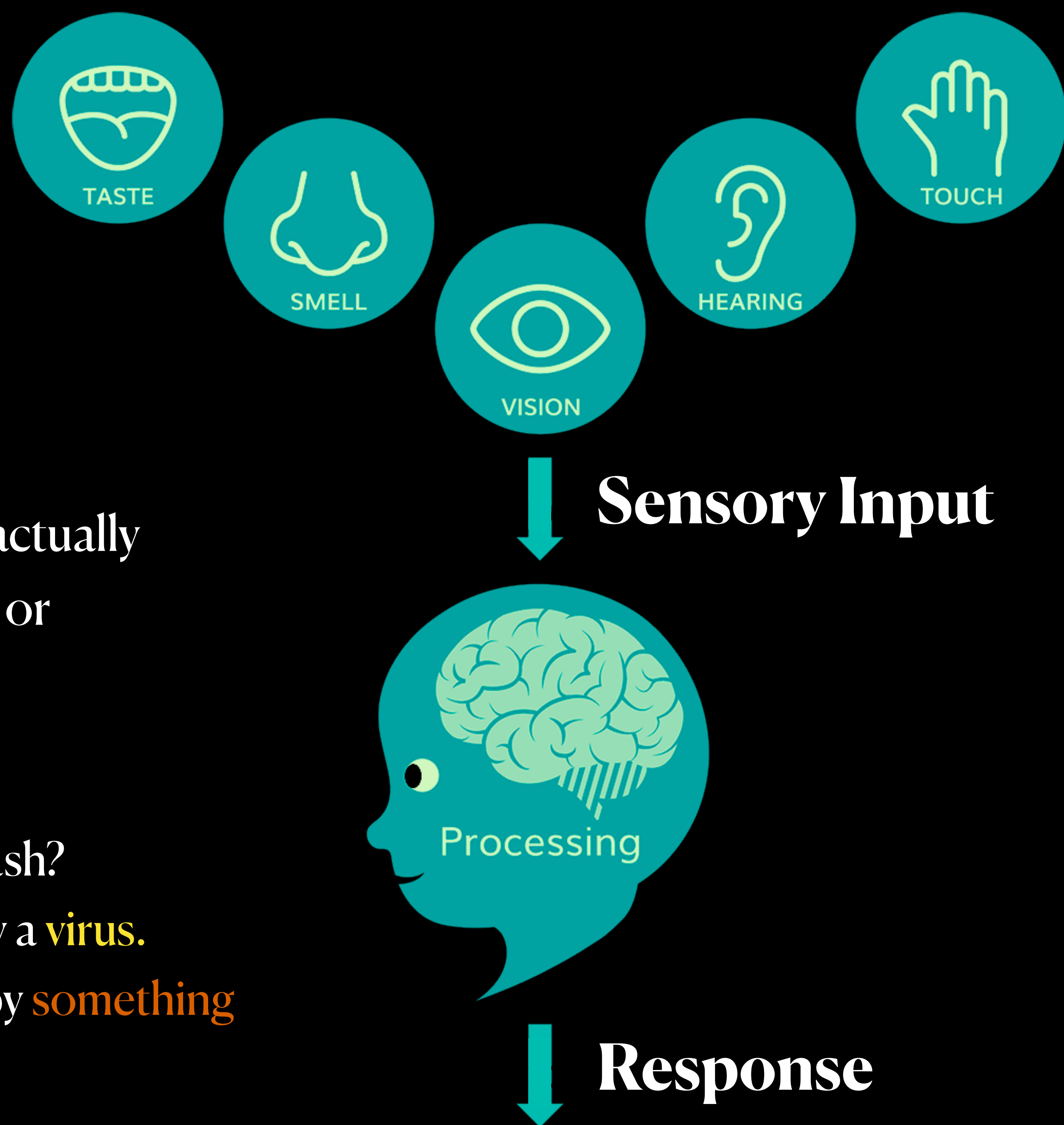
The usage of language

Perhaps the issue arises from our usage of language. Everything that is unobservable actually is directly connected to observable objects or properties thereof.

Example:

Why did Michael develop a rash?

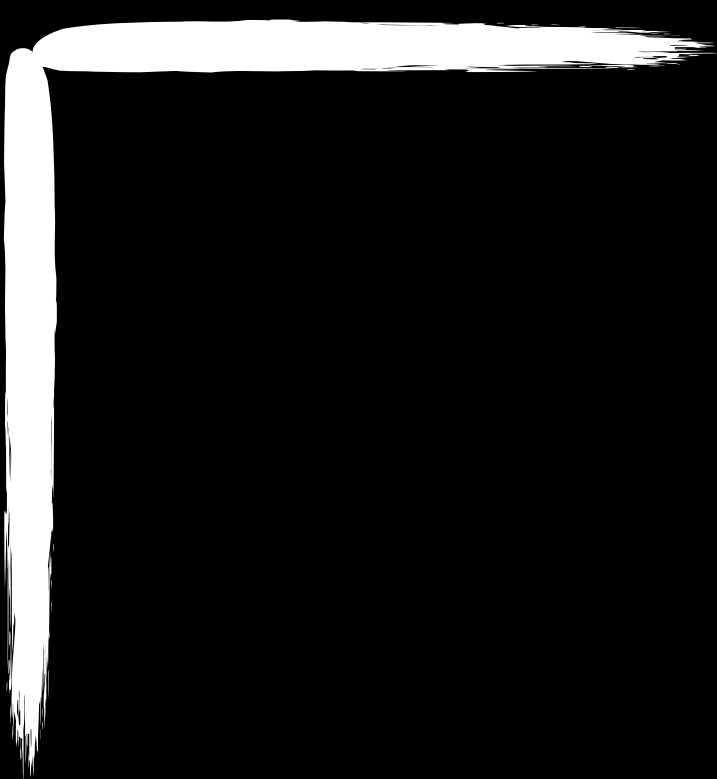
- Because he was infected by a **virus**.
- (Because he was infected by **something which gives rise to rashes**)



Empiricists like Hume and Berkeley were comfortable with the idea of keeping theoretical terms as long as they could be related to observable terms. The theoretical terms would work as abbreviations, summaries, compositions of observable terms (e.g. density).

Theoretical terms that did not satisfy such requirement would be deemed meaningless (e.g. gravity, atoms, etc).

Q: How successful is this project?



Questions?



No Miracles Argument

*Realism is the only philosophy that does
not make the success of science a miracle.*

Putnam 1975 –

Science's great and ever-increasing predictive power, its “instrumental success” allows ever-increasing technological interventions in the world, and this begs for explanation.
Why does science work? The realist will obviously say: because it is (approximately) true.

It'd be a miracle if its success and tech applications were just a matter of luck. By “inference to the best explanation”, where the success of science is that its theoretical terms are real and have their attributes given by their theoretical framework, realists make use of an abductive argument.

Q: Thoughts?



No Miracles Argument

*Realism is the only philosophy that does
not make the success of science a miracle.*

Putnam 1975 –

On one hand,

Explanatory Power: the truth of the theories is the best explanation for their empirical successes

Progress and Continuity: acknowledging past theories' truth elements allows for a conception of scientific progress where newer theories often build upon, rather than replacing old ones

On the other hand,

Underdetermination: empirical success doesn't necessarily imply truth. There might be multiple incompatible theories that can account for the same empirical data

Simplicity: Sometimes, the simpler, less-accurate model is chosen over a more complex, more accurate one because it's easier to work with, indicating that empirical success doesn't always track truth



Pessimistic Meta Induction

On one hand,

Historical Precedence: History is filled with examples of empirically successful theories later replaced (e.g., the phlogiston theory, the caloric theory) - empirical success $\neq$ guaranteed truth

Flexibility: entities posited by theories can be seen as useful fictions, allowing for conceptual change without the metaphysical commitment

On the other hand,

Selectivity: PMI might be cherry-picking examples. Not all discarded theories were genuinely successful, or they are replaced by theories that retained much of their core content

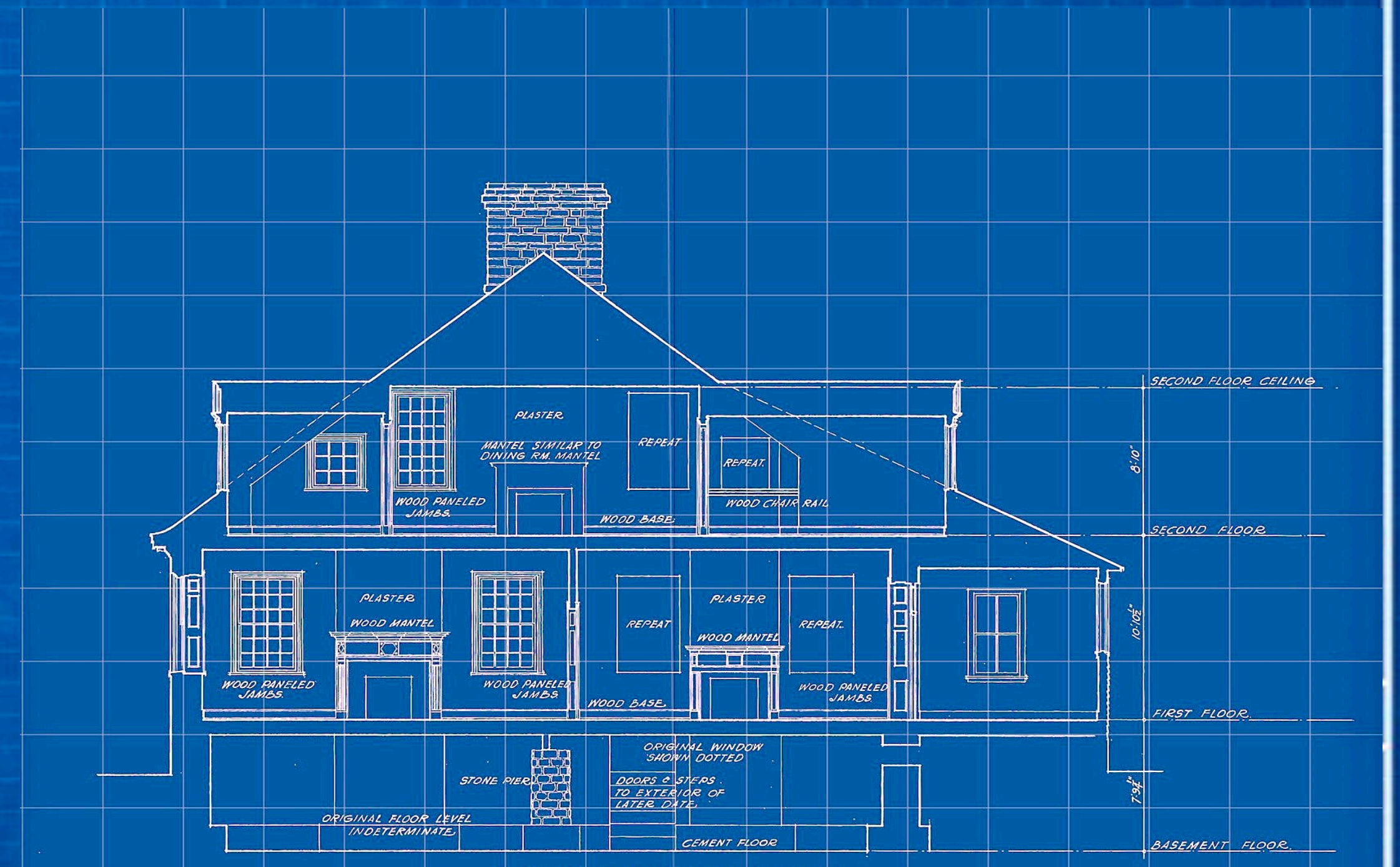
Progress: PMI seems to deny the idea of scientific progress by suggesting that current successful theories aren't necessarily closer to the truth than their predecessors

Q: Thoughts?

Structural Realism

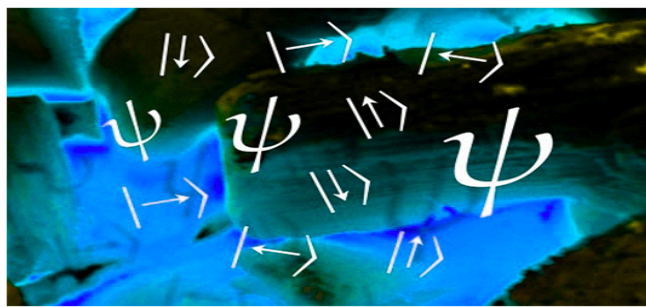
Structural realists will claim that what scientific theories get right is the mathematical structure of reality, without making claims about the nature of things that behave in accordance with these mathematical formulations .

However, how to distinguish the mathematical structures of a theory from its content? What to do when theories have more than one mathematical formulation that are equivalent? And what about theories that are not mathematical by themselves?



Interpretations of Quantum Mechanics

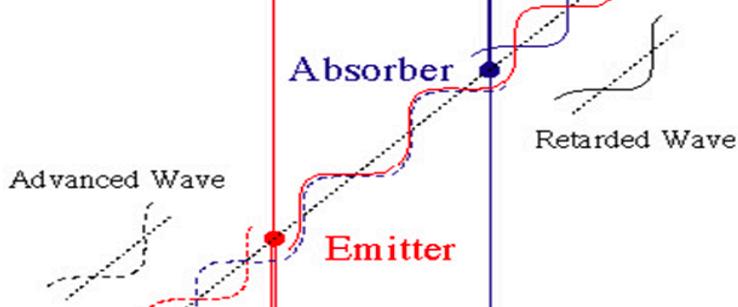
Hidden-Variable Theory



we just don't know (yet)
deterministic
God does not play dice!

Lawful Good

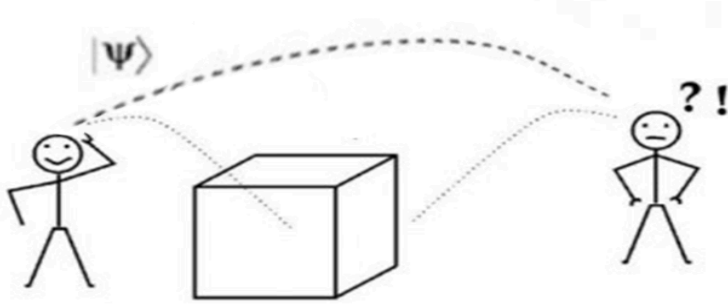
Transactional Interpretation



waves through time
quantum handshakes
explicitly non-local

Neutral Good

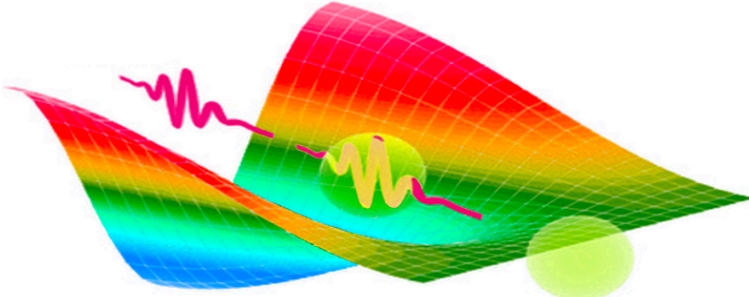
QBism



reality is observation
participatory realism
subjective Bayesianism

Chaotic Good

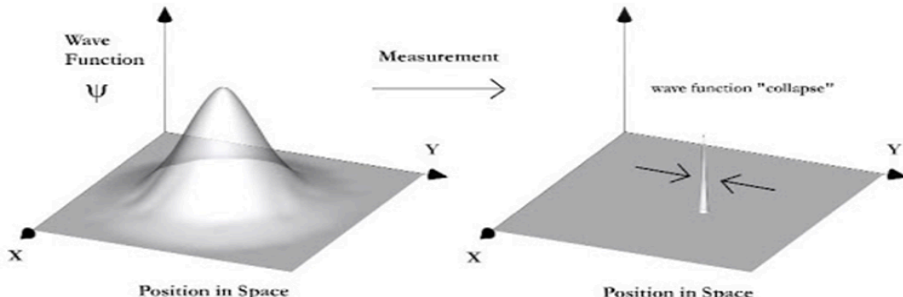
Pilot Wave Theory



wave function & actual state
deterministic
explicitly non-local

Lawful Neutral

Copenhagen Interpretation



probability wave $\rightarrow$ collapse
indeterministic
playing dice, but that's okay

True Neutral

Many Worlds Interpretation



every state a new world
decoherent
infinite universes

Chaotic Neutral

Superdeterminism



everything is predetermined
Bell's theorem loophole
quantum fuzziness is not real

Lawful Evil

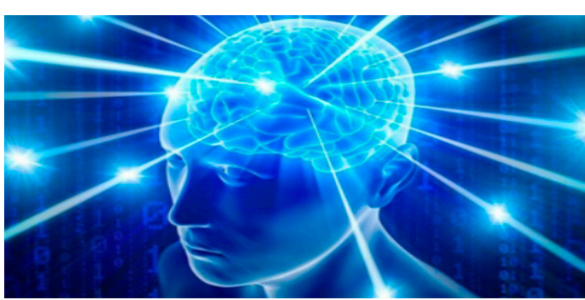
Ensamble Interpretation



probabilities in groups
minimalist
statistics go brrr

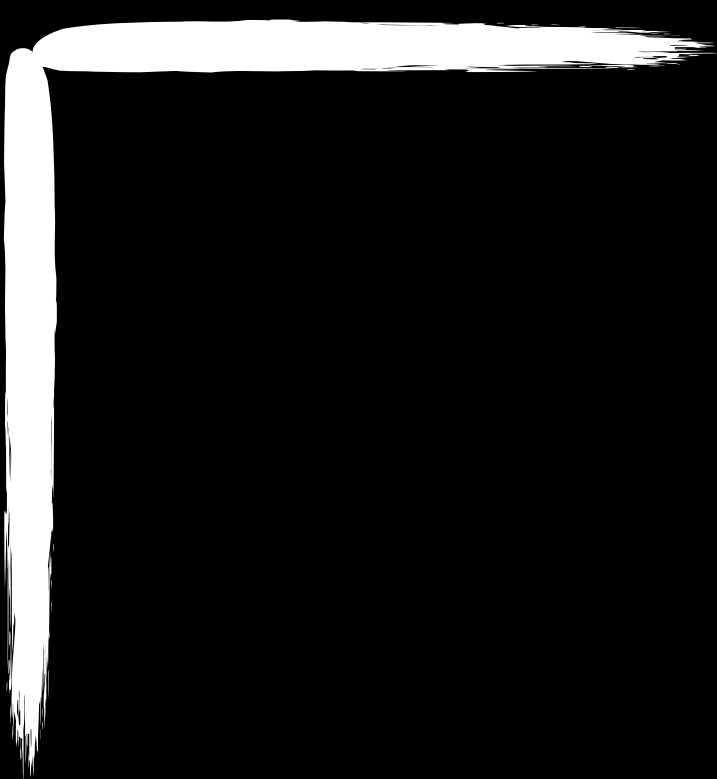
Neutral Evil

Quantum Mysticism



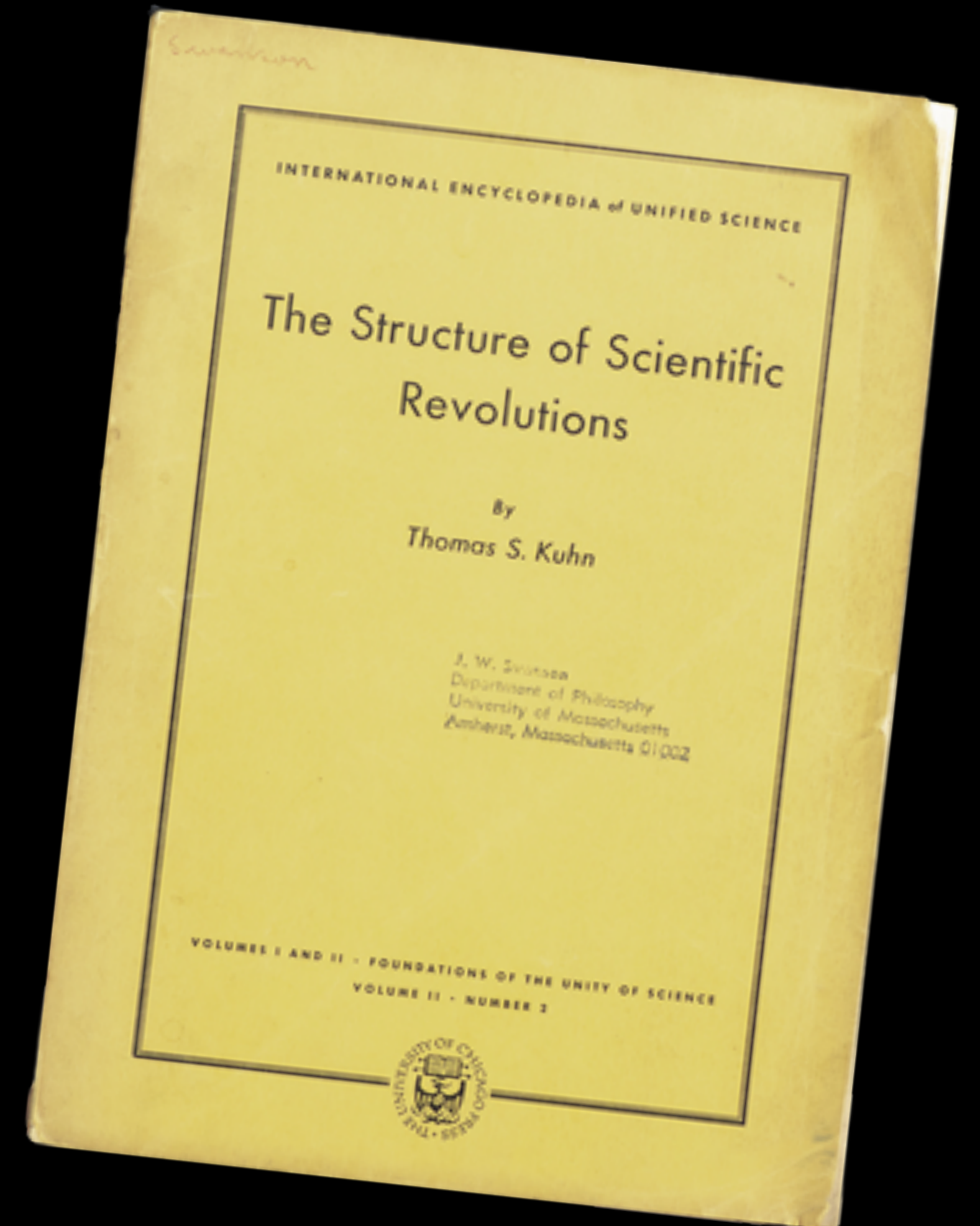
consciousness causes collapse
spooky
Philosophy > Physics

Chaotic Evil



Questions?

Thomas Kuhn



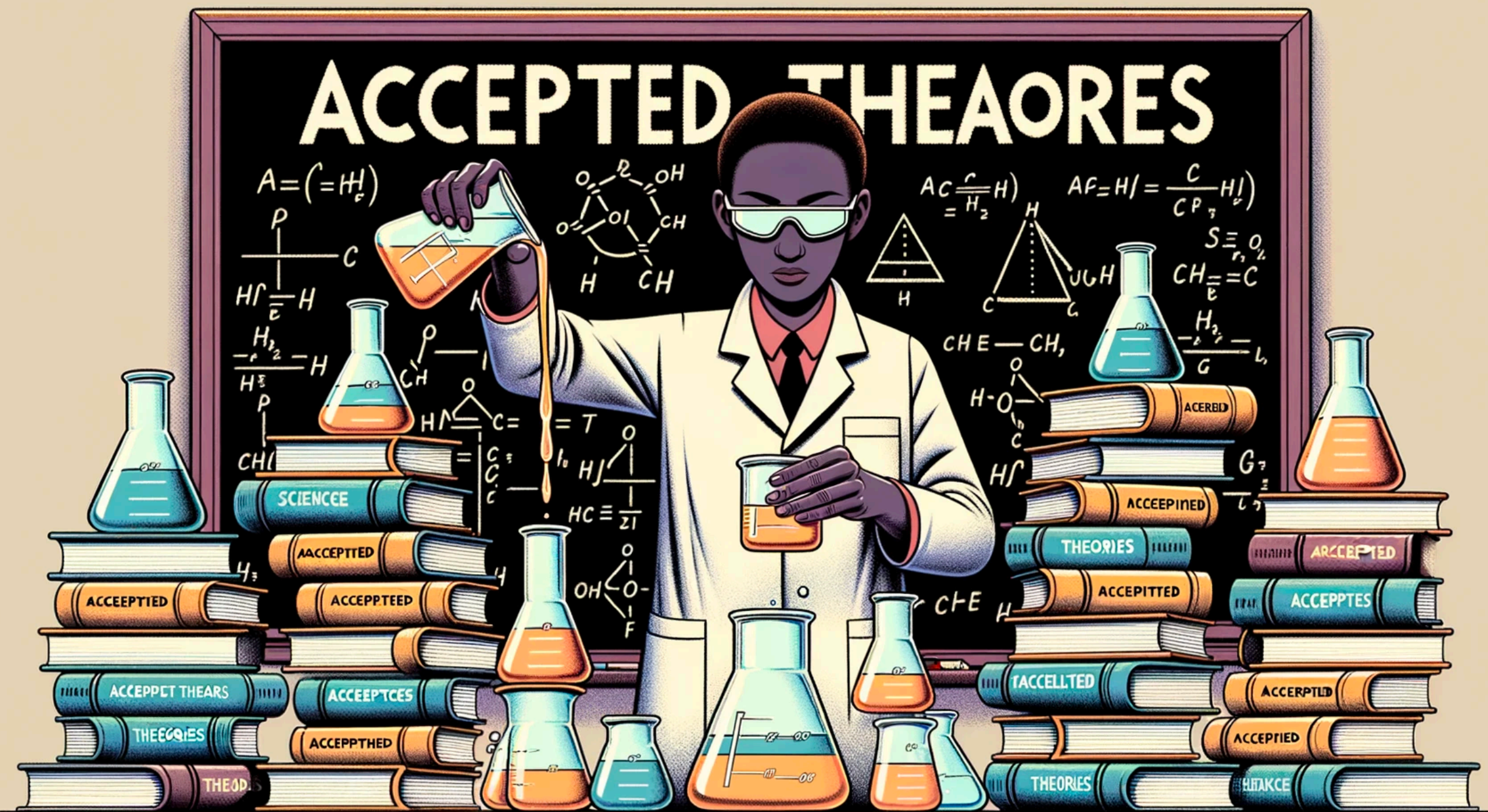
Normal. Science.

when the methods, instruments, directions, and problems that scientists focus on are determined by the current **paradigm**.

The paradigm goes beyond just simply formulation of the theories, as it also takes into account all the commitments that come with them.

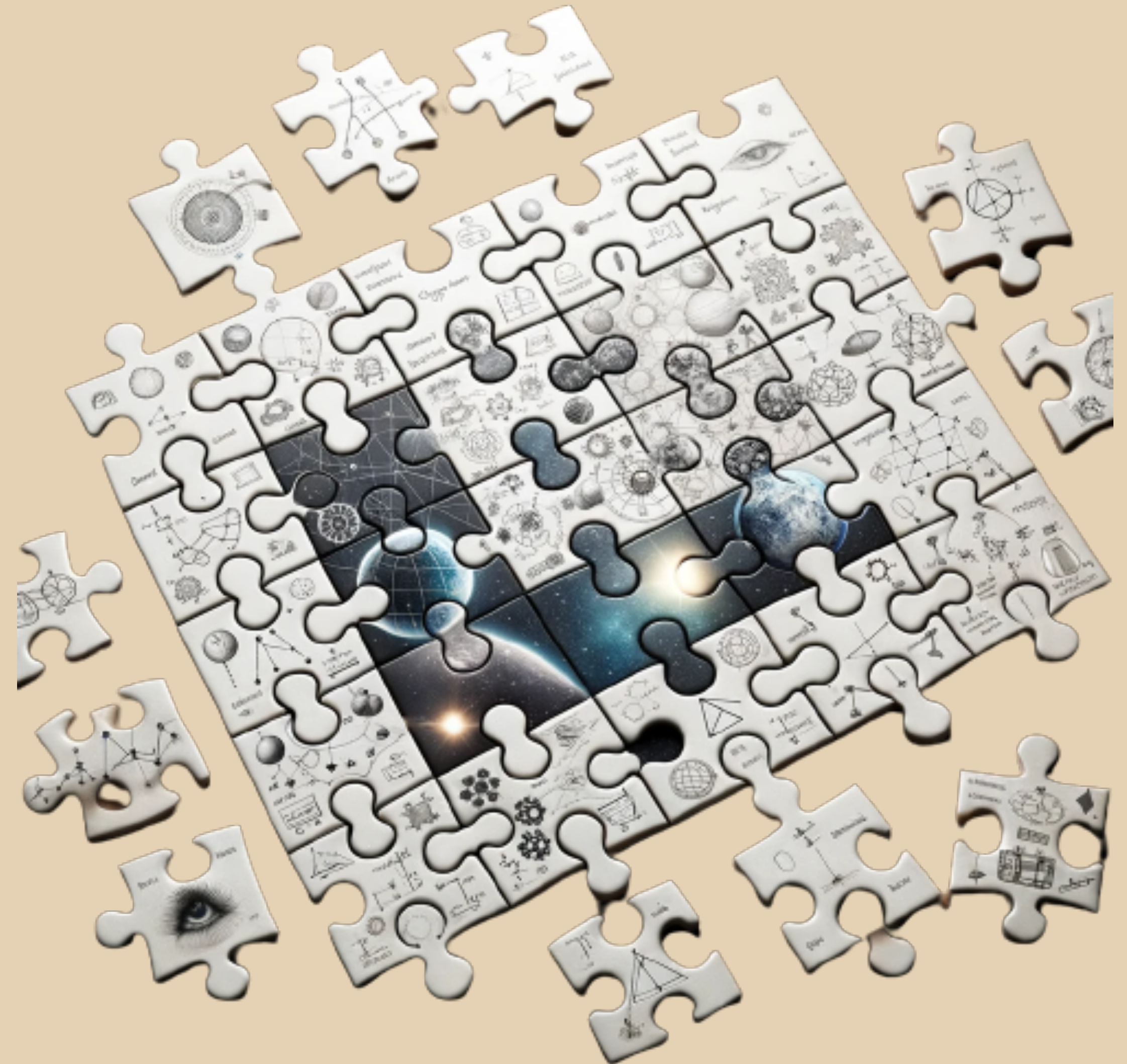
It's a “way of doing science”.

Q: Examples?



Kuhn's notion of paradigms has important philosophical implications for the nature of science:

1. Paradigms are **holistic**
2. Observation is **theory-laden**
3. Meaning is paradigm-dependent
4. Paradigms dictate ontology



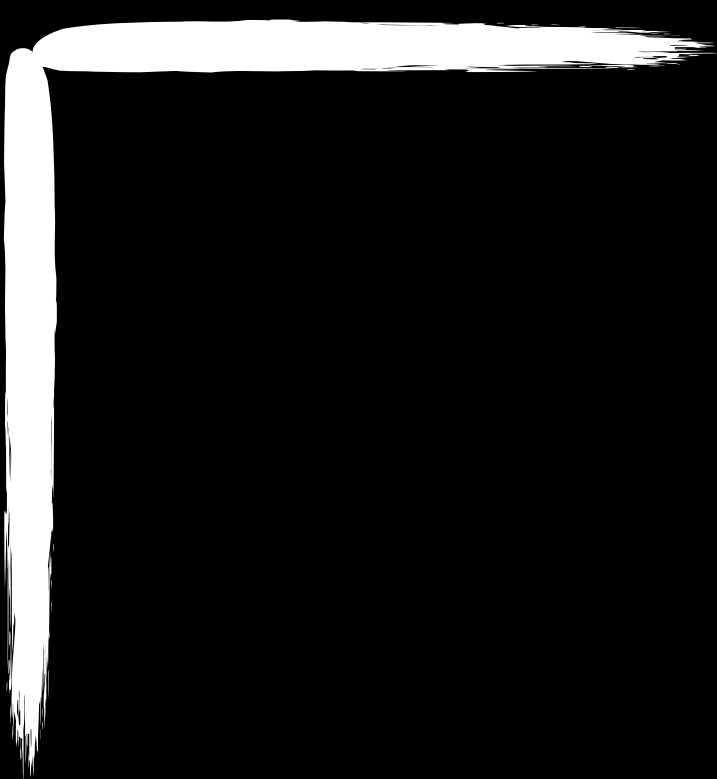
During periods of **normal science**, research focuses on pushing the frontiers of knowledge by applying the paradigm itself to the explanation and prediction of data within its intended domain. The empirical focus tends to be towards:

- obtaining greater precision in previously established observations
- establishing facts that reinforce the paradigm
- experiments undertaken to solve problems to which the paradigm draws our attention

Normal science is also reflected in textbooks and the **consensus on the approaches to teach any given subject which is paradigmatic**. At the same time, **when that's not the case**, typically in the special sciences, that will reflect that **the discipline remains pre-paradigmatic**.

Q: Examples of current pre-paradigmatic science?



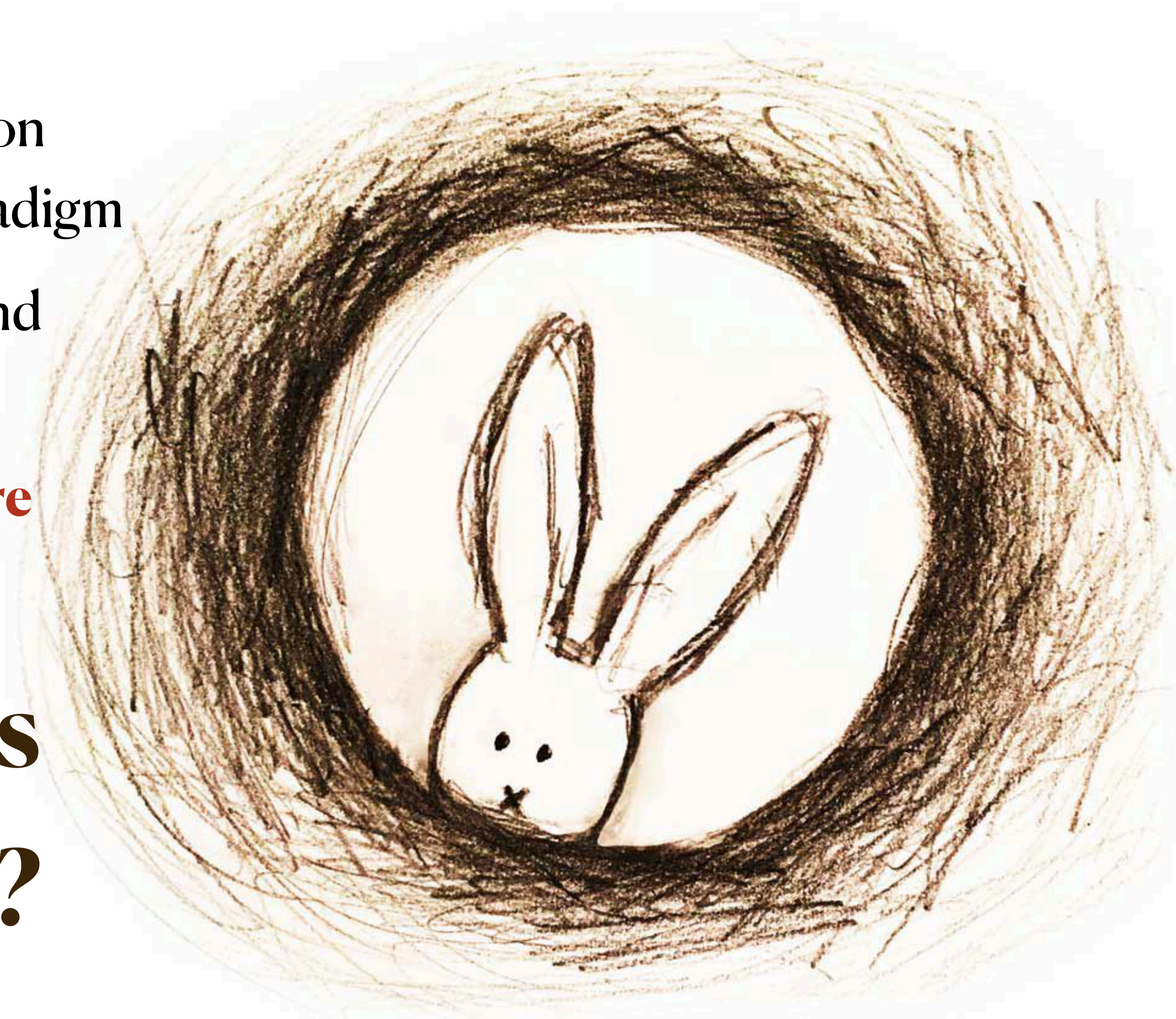


Questions?

Kuhn made use of **several psychological experiments** to argue that **observations are not taken neutrally**, but rather they are interpreted within the paradigm itself:

- Our descriptions of our measurements depend on theoretical concepts that operate within the paradigm
- Our paradigms determine which observations and experiments are salient
- **Perhaps, even our perceptions themselves are theory-laden**

**How deep is
the rabbit hole?**



**What color is
this?**

**What color is
this?**

Experiment on color perception: researchers found that Russian speakers, who have separate words for light blue ("goluboy") and dark blue ("sinii"), can distinguish between these shades more quickly than English speakers, who generally use the term "blue" for both.

This difference even manifests neurologically; when the colors shift from light to dark blue, Russian speakers' brains show a "surprise response," indicating a category shift, a response not observed in English speakers. In this case, **the language we speak acts as a paradigm that not only influences how we describe the world but also how we perceive and interact with it.** It illustrates how our linguistic framework can shape our cognitive processes, supporting Kuhn's notion that paradigms come with embedded assumptions that often go unnoticed but significantly influence how we approach scientific inquiries.

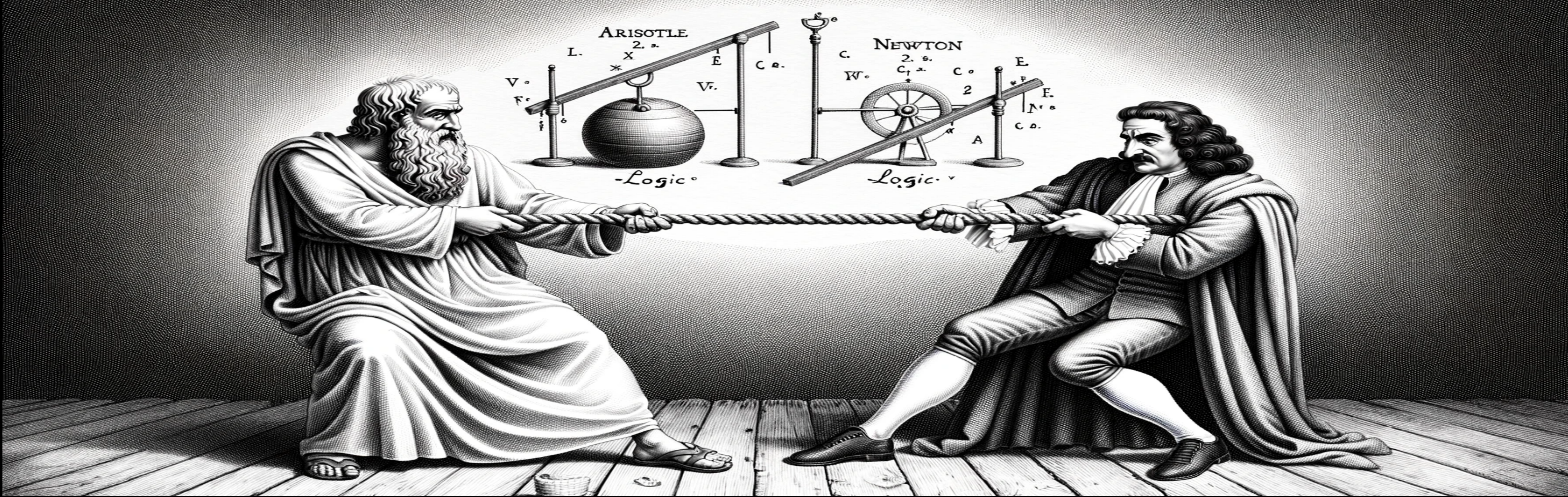
Scientific Revolutions

A new paradigm emerges and replaces the old one:

1. **Anomalies** appear within the normal scientific period reflecting problems to account for some data
2. If they persist, it becomes a **crisis**
3. Slowly, the crisis draws attention of more and more scientists that start to focus their efforts on resolving it, until most of the discipline's research program orbits the unsolved anomalies
4. Usually, it happens that some scientist, quite often younger, proposes **a radical solution to the problem**, which takes seriously that the anomaly hints towards a departure from the ideas of the current paradigm.

Q: Examples?



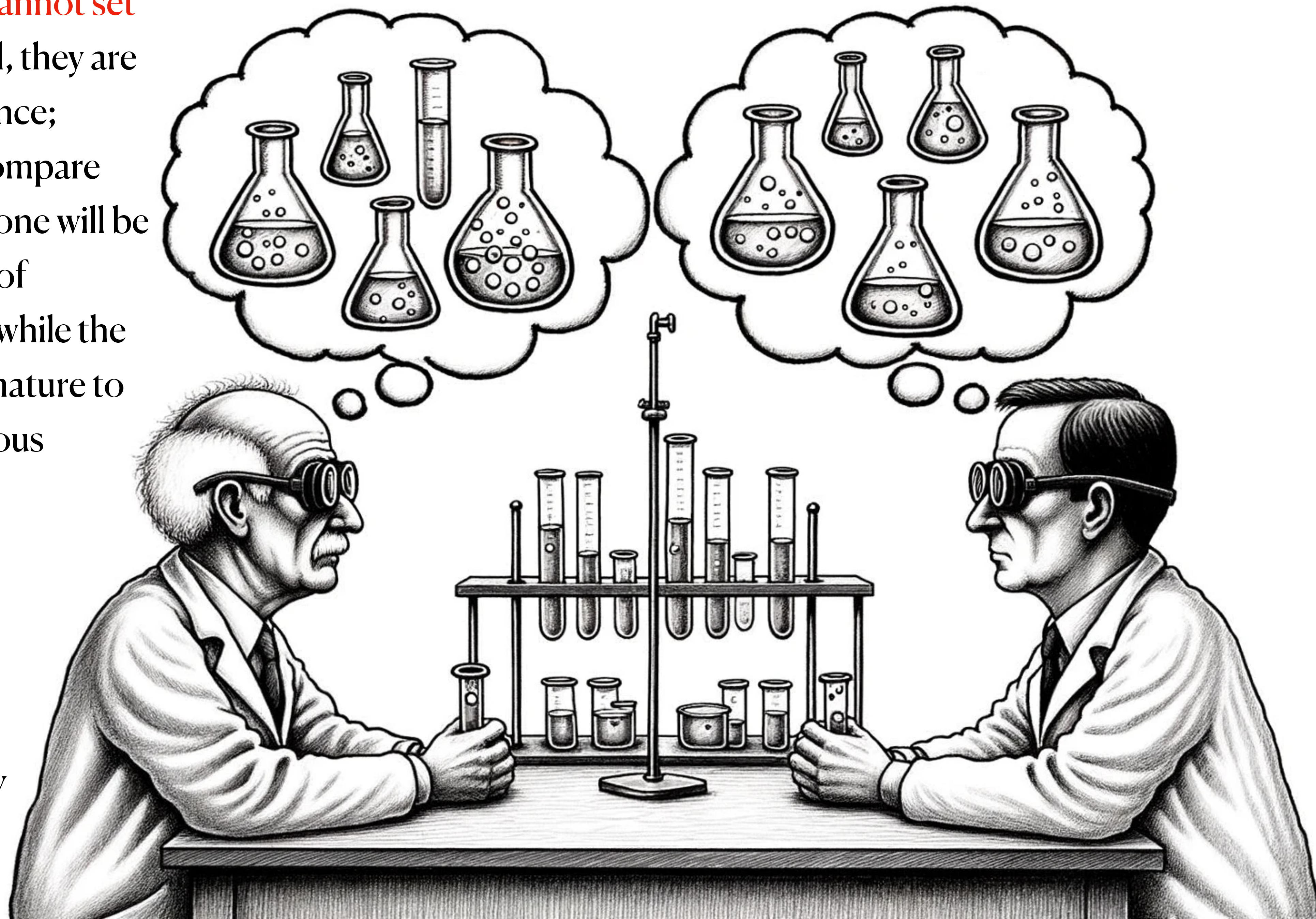


During the period of competition between paradigms, **scientists do not act in a completely rational way.**

On one hand, it takes some degree of blind belief to let go of the old paradigm and all the weight that comes from its accomplishments to focus on anomalies as the source of inspiration for a radical new understanding of nature; **on the other hand**, to insist on the old paradigm over and over again after a long period of crisis can be seen as denial, especially in light of the history of science.

Meanwhile, **observations cannot set the competition**. First of all, they are the very cause for its existence; second, it will be hard to compare both paradigms as the old one will be down-weighted for its way of accounting for anomalies, while the new one might be too premature to properly account for previous evidence.

For Kuhn, it will not be possible to decide between the paradigms in a clearly rational matter.

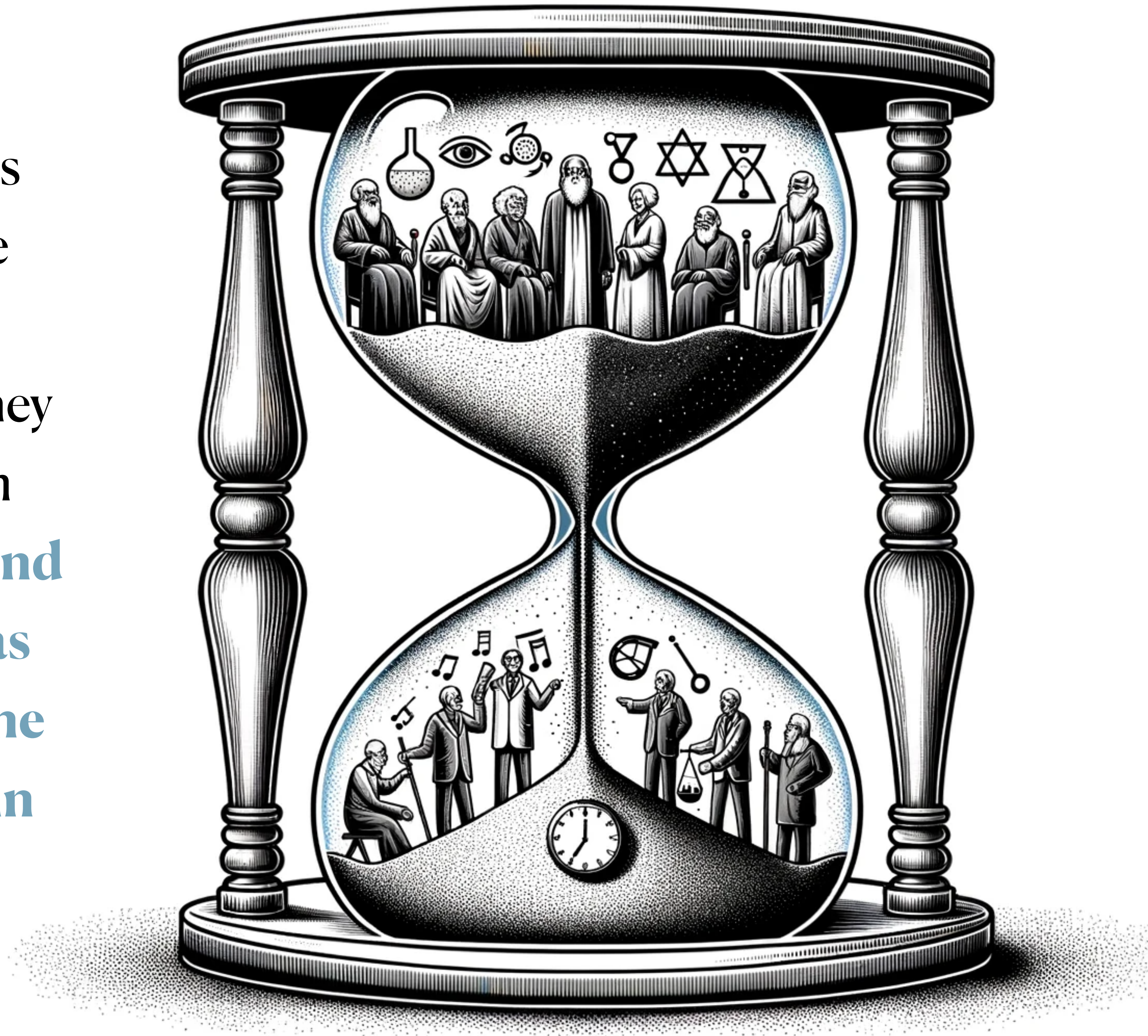


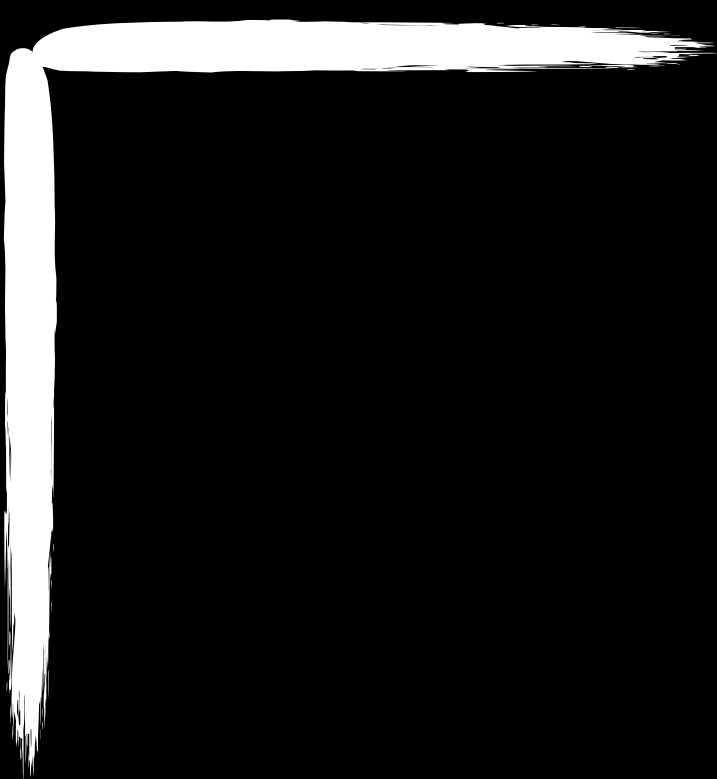
Kuhn argues that embracing different paradigms is analogous to be living in different worlds, to the extent that they are **incommensurable** with one another: **it's not even possible to translate all the statements across the different paradigms.**

This is the reason why **he would argue that paradigms do not improve on one another**, that science does not accumulate in the direction of successive approximation to the truth, and something that was not a problem within a paradigm can become a question that needs to be addressed in another.



As a change of paradigm involves such a big change of world-view, quite often it is too big of a shift for well-established scientists. Not only will they resist to the change, but most of them might not be able to make the shift. **And literally old paradigms fade away as their proponents die off, leaving the proponents of the new paradigm in command of the field.**





Questions?

[illegible]

^{ἐν}κοίλῳ νύκτι. δάκρυ δ' ἄρα γόησι μὲν.
^{ἔχ}ω λῶς δ' ἐμὴ φίλῃ τῇ.
^{ὡς} ἰδὲ νύκτι ποίσι πυρρὰ λείπει ποναίῳ.
^{αὐ}τίκ' ἀλ' ἄντι πυρρὰ, τὰ ξέκλκον δ' ἄντι ποίσι.
^γαίης δ' οὐ μάλιστ' ὑπὲρ κλυτὰμφιβυήας,
^πρὸς δ' αἰδομένη κεκρομένη δ' ἐβουλάσ.
^ῥωσὲ δ' ἐκ κοίτης θελ' ἔλαυνε κῶ πρὸς λήνῃ.
^λρυφέη δ' ἄντι. κλυτὰ κρῆν' ἐκ κλυτὰ πρ.
^δαιδάλεω χάρων κλυτὰ χεῖθε. θαῦμα δ' ἐστίν.
^ἀμφι δέ οἱ, στεφάνῳ νεοσθένος δ' ἄντι ποίσι,
^ἰμὲρ τῶν, πρὸς θεοὺς κλυτὰ πρὸς λήνῃ.
^ἀμφι δέ οἱ, στεφάνῳ χεῖθε κλυτὰ φινέσκον.
^τὴν αὖτε ποίησ' ὑπὲρ κλυτὰμφιβυήας.
^λοκίως δ' ἄλλοι. χάρων δ' αὖτε ποίσι.
^τῇ δ' ἄντι, δαιδάλεω πρὸς τήν. θαῦμα δ' ἐστίν.
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^κρυάλλος δ' ἄντι πρὸς τήν. θαῦμα δ' ἐστίν.

Greek Mythology

χρυσὸν καὶ χρυσὸν. ὁ
ρίνη τὸ ὀνόματι:-



Chaos
(by Wenceslaus Hollar)



Gaia
(by Anselm Feuerbach)



Tartarus
(by John Martin)



Eros
(by Ascoli Satriano)



Gaia
(by Anselm Feuerbach)



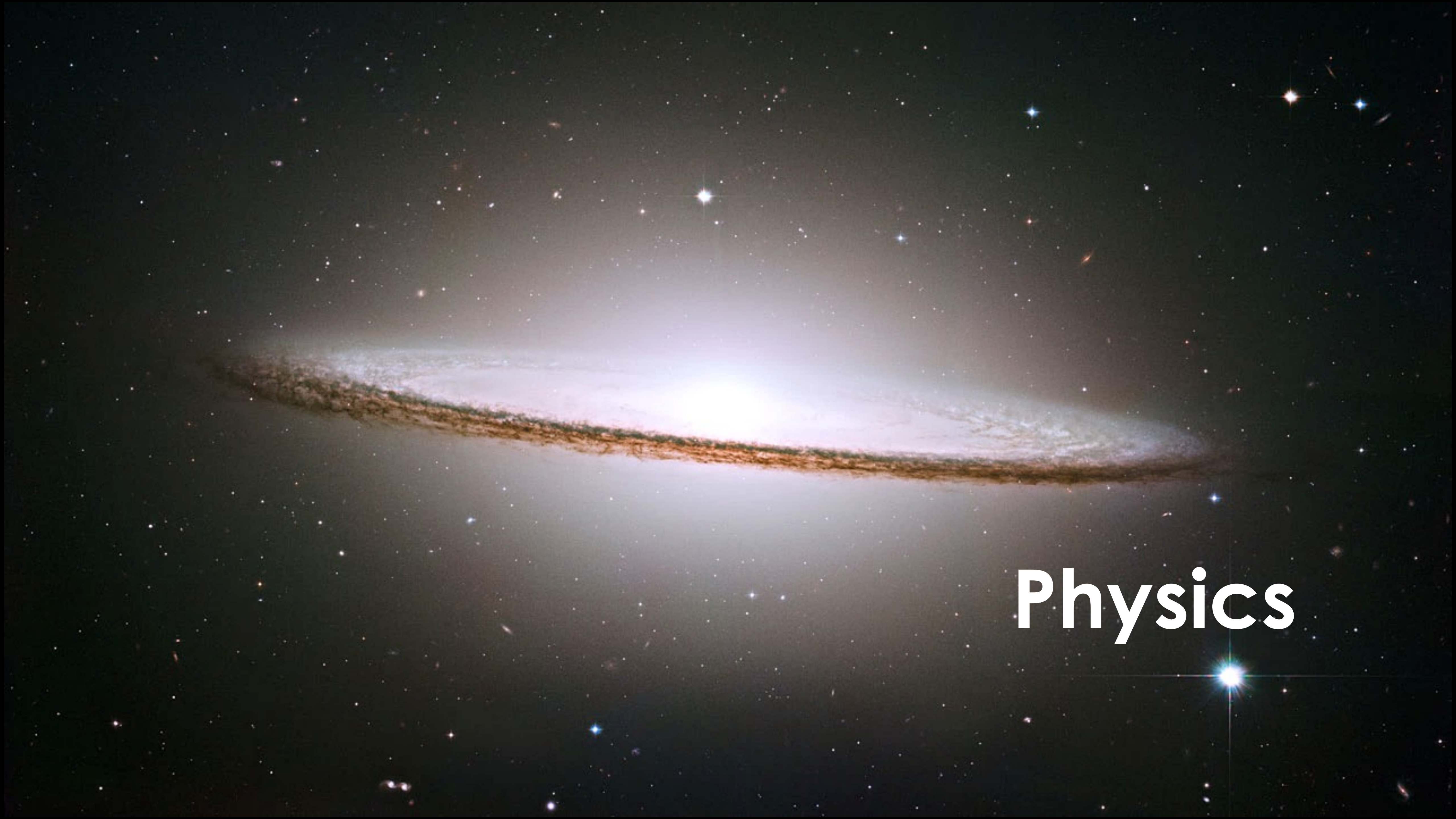
Ouranos
(mosaic in Sentinum)



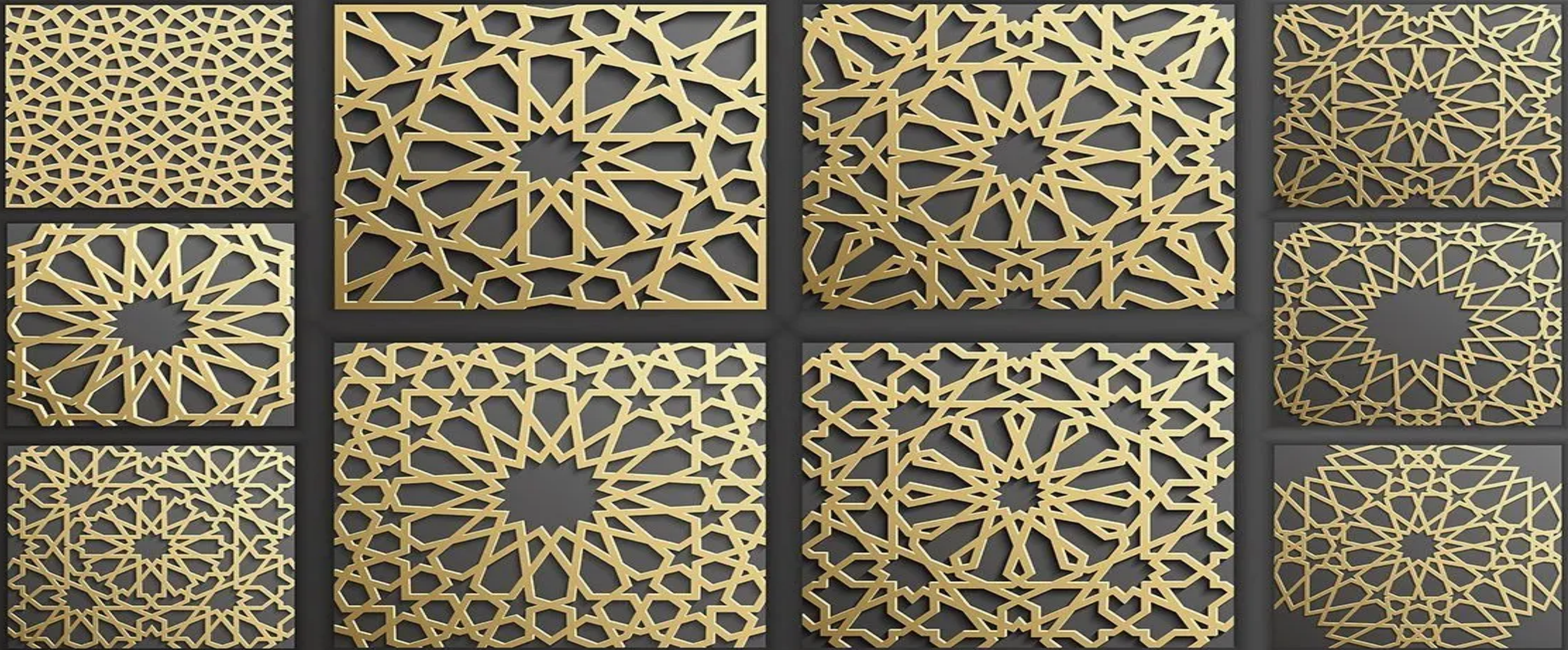
Cronus
(by Giovanni Romanelli)



The Mutilation of Uranus by Saturn
(by Giorgio Vasari and Cristofano Gherardi)



Physics



Patterns → Conservation

But why are there patterns in the world? Why are there things that are conserved?



But why are there patterns in the world? Why are there things that are conserved?

There is a danger in asking “why” questions in physics, and in general, as there is no guarantee that we can keep asking them. But at least in the case of conservation laws, we know that they are intrinsically related to the existence of *symmetries* in the world.

It turns out, that the laws of physics are symmetric under time and spatial shifts/translations, and leading to the conservation of energy and momentum. There is also a symmetry around rotations, which leads to the conservation of angular momentum.



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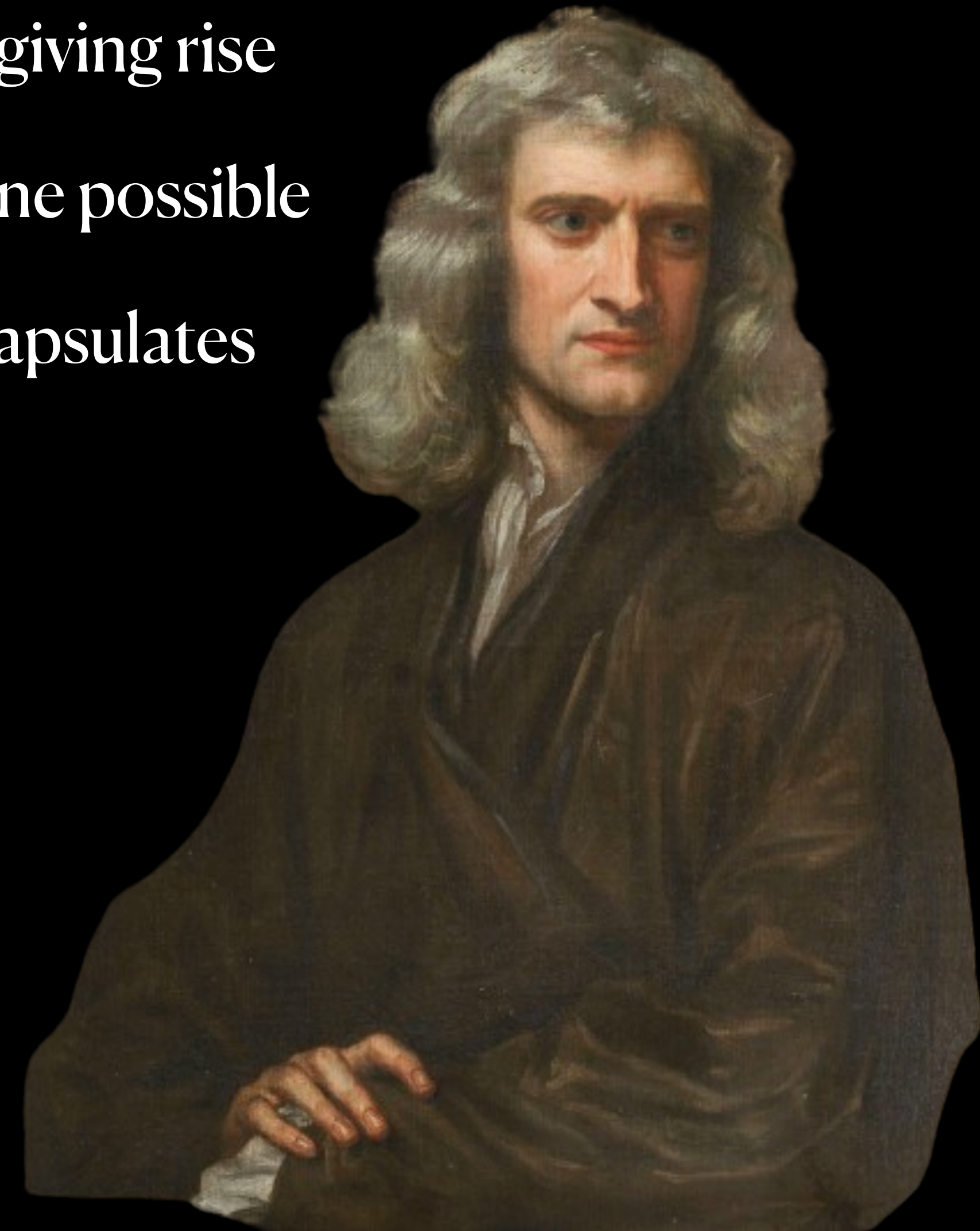
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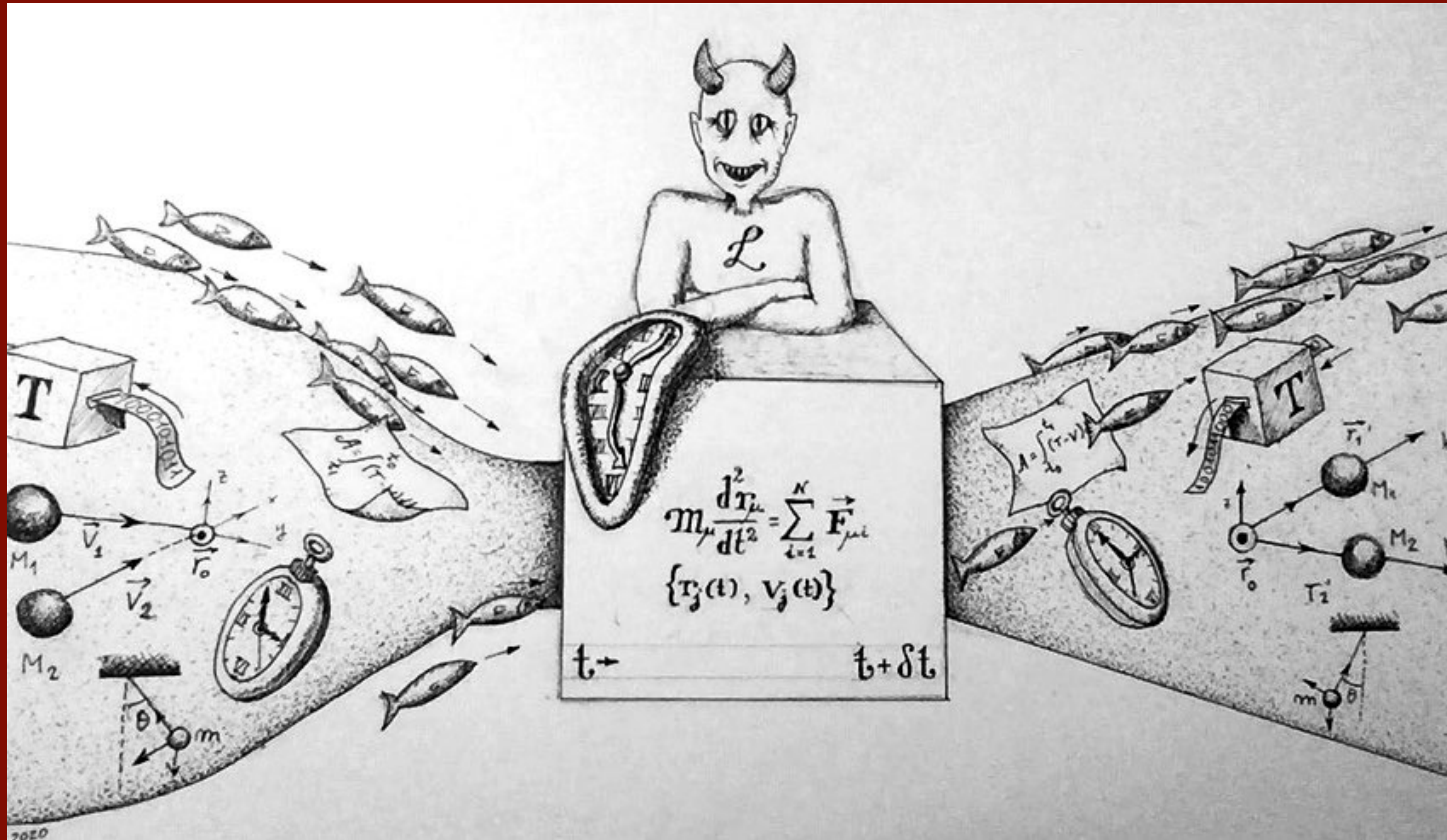
Q: Are they conserved though? Others?



It was only with Isaac Newton in 1687 that for the first time some patterns were brought together into fundamental physical laws, giving rise to the framework of **classical mechanics**. Newton's laws were one possible formulation of what's known to be the classical world, and it encapsulates some underlying principles:

- it is made of things with definite, measurable values, obeying **deterministic** equations of motion
- **time and space are taken to be absolutes**

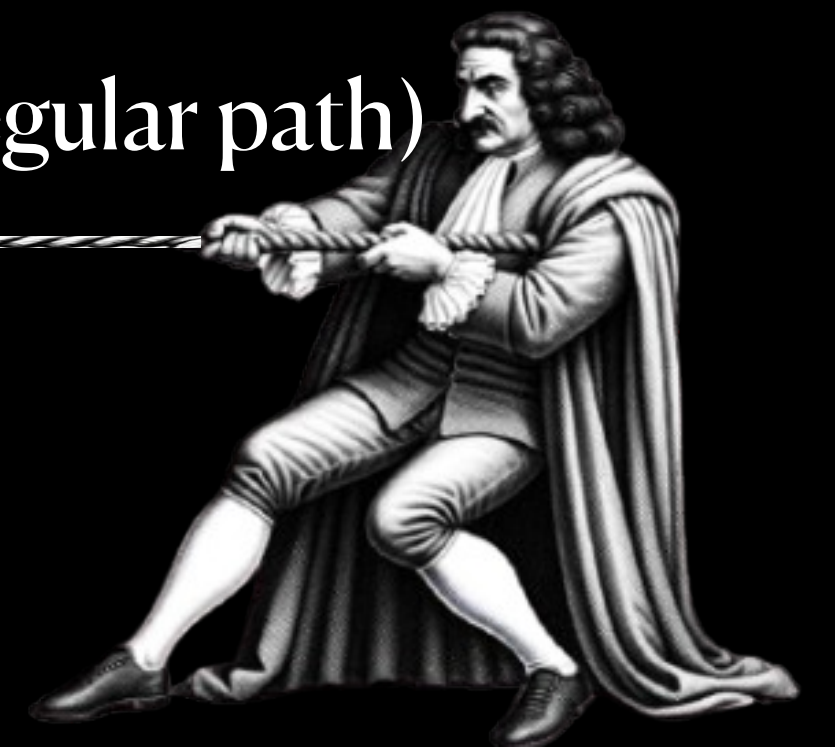




Q: Does entropy increase for Laplace's demon?

Philosophical Shift in Understanding Motion:

- **Aristotle's Teleological View:** Motion as goal-oriented; objects have tendencies toward an end point (e.g., material things tend toward Earth)
- **Kepler's Global Patterns:** Defined orbits based on observed patterns; planetary motion seen as a whole trajectory, moving from goal-oriented to a fixed global pattern
- **Newton's Laplacian Paradigm:**
 - Current state (velocities and positions) fully determines the system's future
 - Patterns, such as planetary orbits, are outcomes of underlying laws rather than goals or inherent tendencies
 - The laws apply universally/locally, even when patterns are absent (e.g., a comet's irregular path)





$$\vec{F} = m \frac{d\vec{v}}{dt}$$