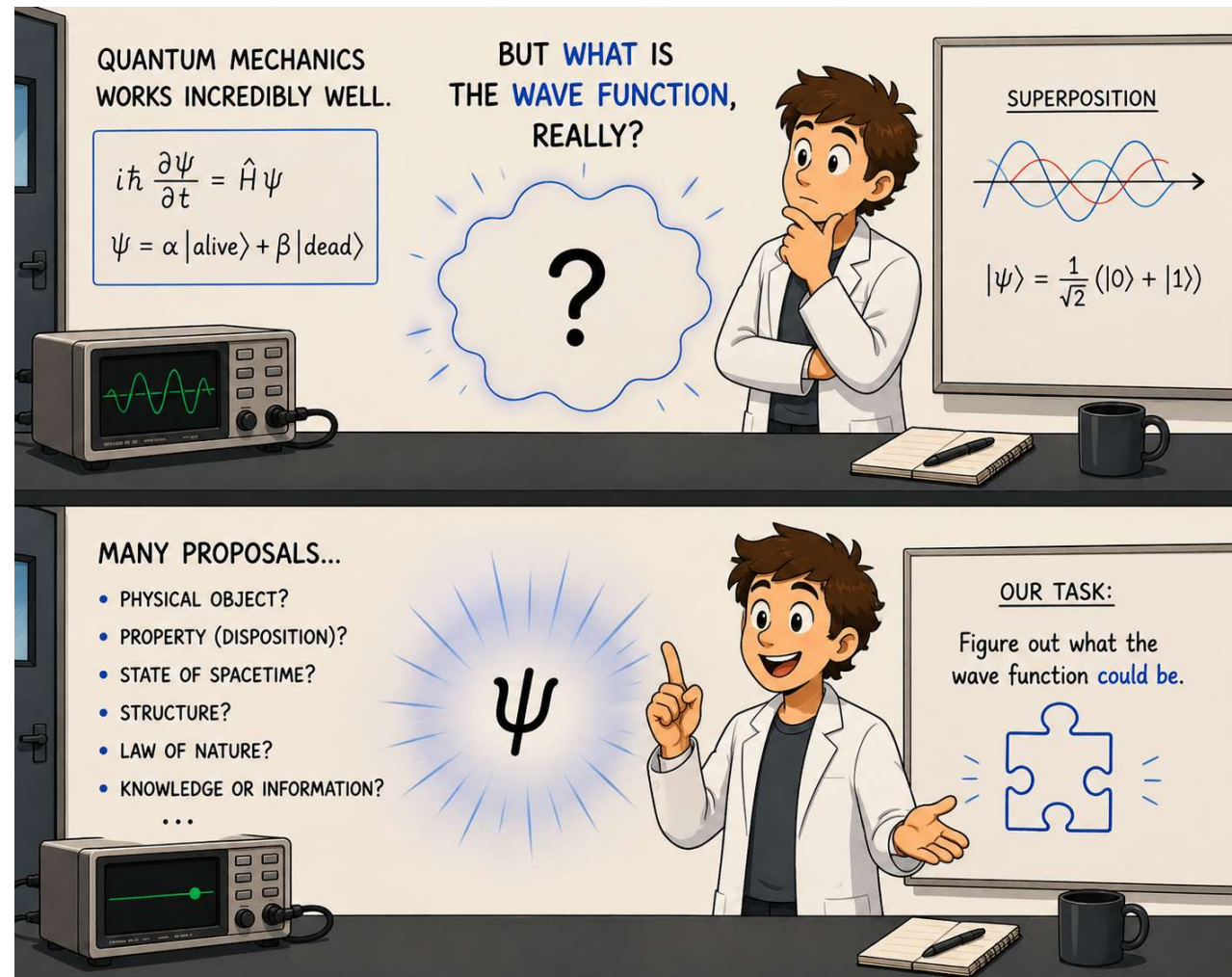


Reality, Explanation, and the Wave Function

PART II:

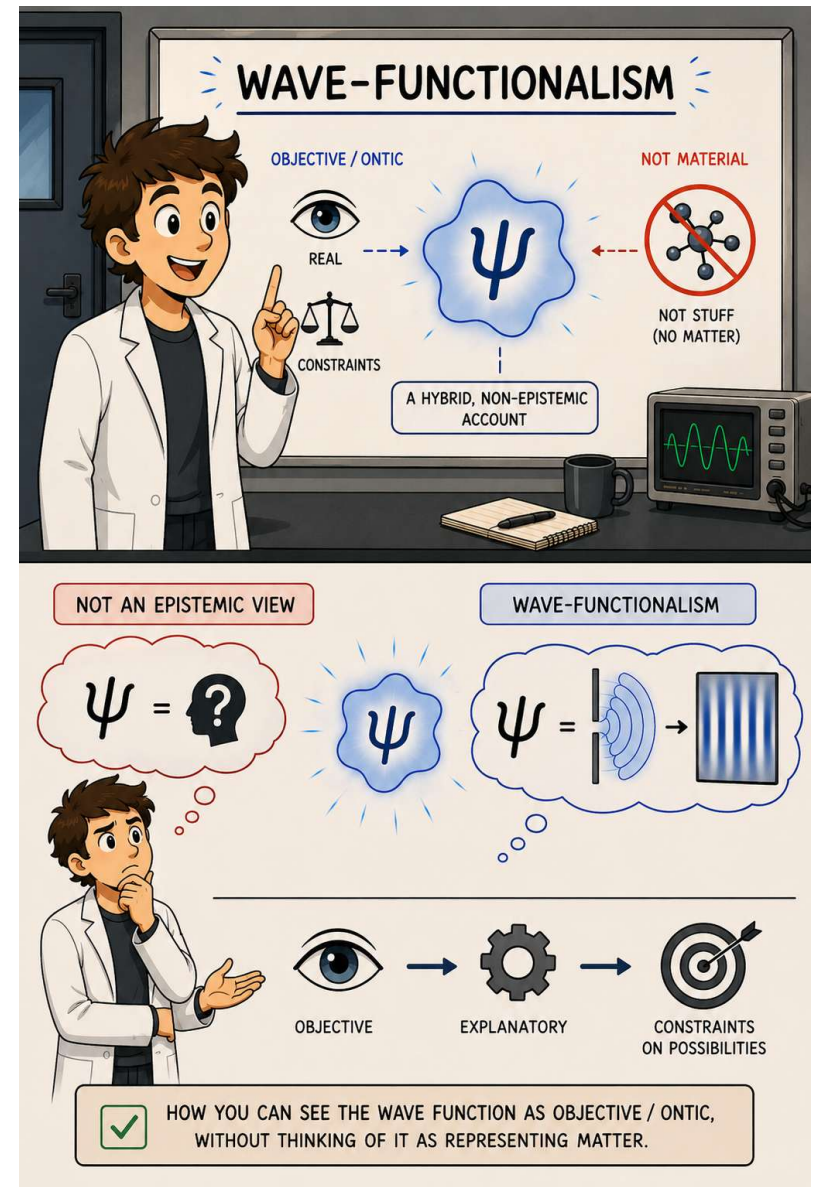
The wave function is as the wave function does

- Valia Allori -- Unibg
- June 16, 2026
- XXIX Urbino International
Philosophy of Physics
Summer School



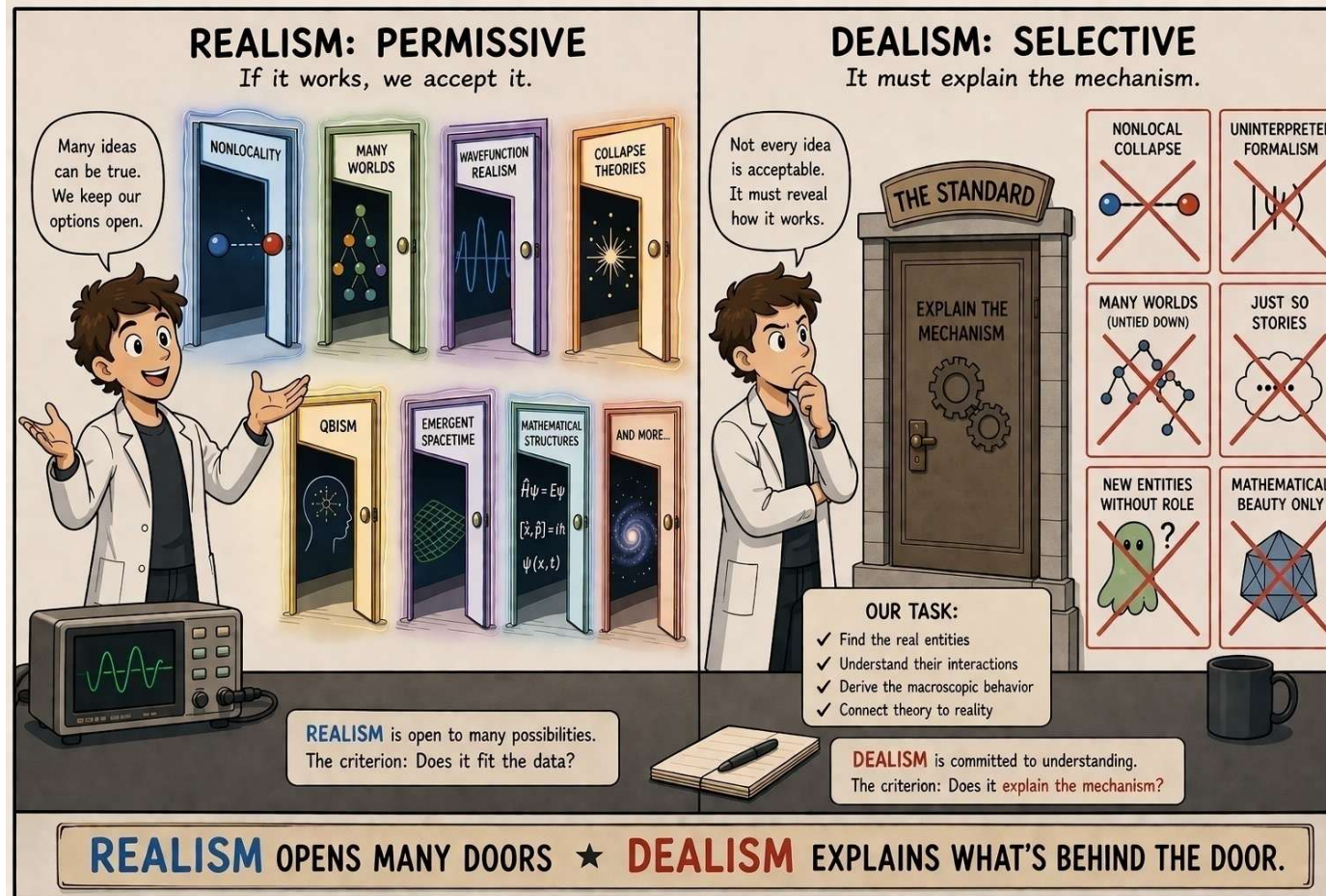
Outlook

- **In Part I:** if you are a Dealist, it is just natural to think of the wave function as **NOT** describing matter
- **Here, in Part II:** what is the wave function then?
- Discuss “wave-functionalism”: a **hybrid, non-epistemic account** of the meaning of the wave function for those who **do not** want to think of the wave function as “material”



Reminder of what Dealism is

- **DEALism** – “what’s the *real DEAL* behind the phenomena?”
- The Dealist Methodology:
 - 1) Anti-mystery principle: **weirdness is a diagnostic of failure**
 - Realism: “QM is strange but true”
 - Dealism: “If it’s that strange, we probably haven’t explained it yet”
 - 2) Balance **simplicity and explanation**: start with the obvious; escalate only when it adds explanatory power
 - 3) Priority of explanation over accommodation in order to **understand**
 - Realism: saving the phenomena is enough to take a theory seriously
 - Dealism: explaining the macroscopic dynamics in terms of the microscopic dynamics (from past empirical success)



Quantum Dealism: what is the wave function?

- Natural Realist attitude: **the wf is (represents) some physical object**

- The wave function is the main object of quantum theory, the one which the theory describes the evolution of
- So, if someone wants to be a **realist** about something in the theory, it should be the **wave function (analogy with classical mechanics)**

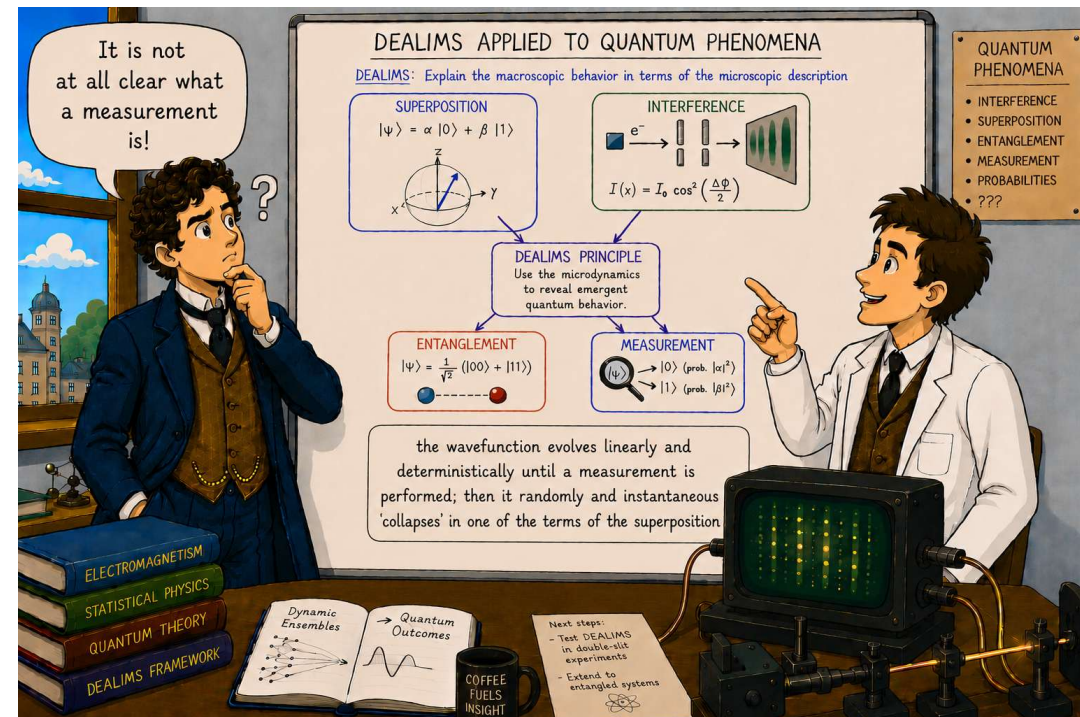
- However, the **Dealist would reject** this because:

OPTION 1: With the collapse of the wave function, the theory is empirically adequate from the start...

Good, but ...

- Implementation 1.A of the collapse: the vN rule

- it is unclear what a measurement is: mysterious mechanism/ontology...



Quantum Dealism: what is the wave function?

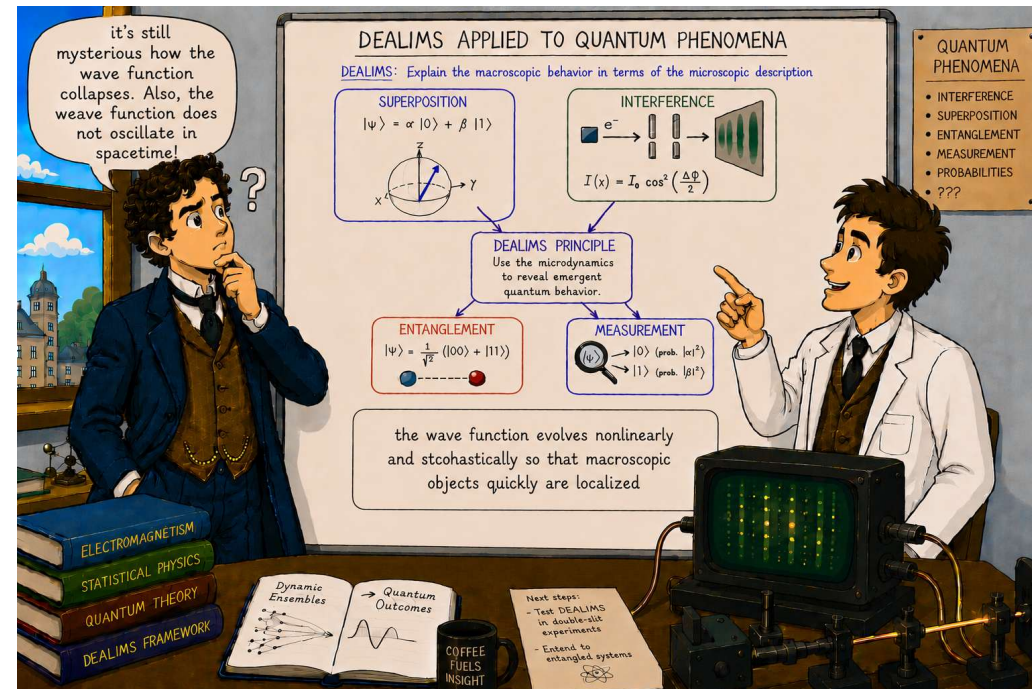
- Natural Realist attitude: **the wf is (represents) some physical object**

- However, the **Dealist would reject** this because:

OPTION 1: With the collapse of the wave function, the theory is empirically adequate from the start

- Implementation 1.B of the collapse: spontaneous localization theory

- Unexplanatory: it is still an unexplained postulate that the wave function collapses
- Moreover, even if one were to accept that, the wave function couldn't be seen a field (like EM fields) because it does not oscillate in spacetime, and since there's nothing else, there would be no matter
- (of course there are uncountable other ways to try to fix this. But why should we? First, look at other, simpler, possibilities)



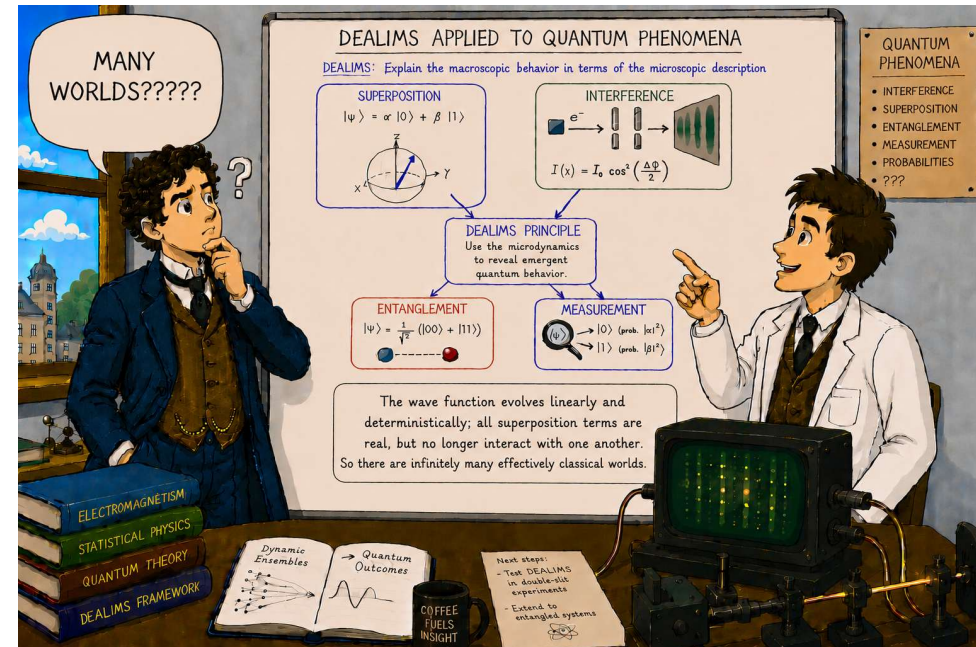
Quantum Dealism: what is the wave function?

- Natural Realist attitude: **the wf is (represents) some physical object**
- However, the **Dealist would reject** this because:

OPTION 2: Without collapse, the theory makes false predictions (produces unobserved macro superpositions)

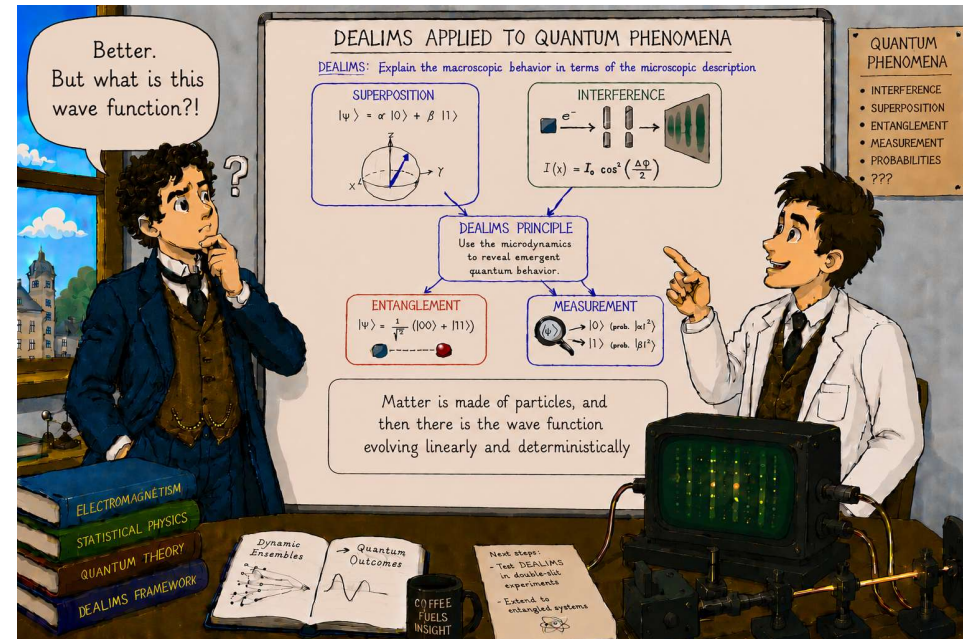
– modification 2.A: “add” an undetectable multiplicity of ‘worlds’ (Everett)

- unreasonable metaphysics/insufficient explanatory power
- Moreover, even if one were to accept that, the wave function couldn’t be seen a field (like EM fields) because it does not oscillate in spacetime, and since there’s nothing else, there would be no matter
- (of course there are uncountable other ways to try to fix this. But why should we? First, look at other, simpler, possibilities)



Quantum Dealism: what is the wave function?

- Natural Realist attitude: **the wf is (represents) some physical object**
- However, the **Dealist would reject** this because:
 - OPTION 2: Without collapse, the theory makes false predictions (produces unobserved macro superpositions)
 - modification 2.B: “add” a field in space evolving in time (Sm)
 - It’s still empirically inadequate because it produces macro superpositions
 - To fix this, you’d need many-worlds again, so no advantage
 - modification 2.C: “add” particles in space moving in time (dBB)
 - Better. But even so: unclear what the wave function is supposed to be!

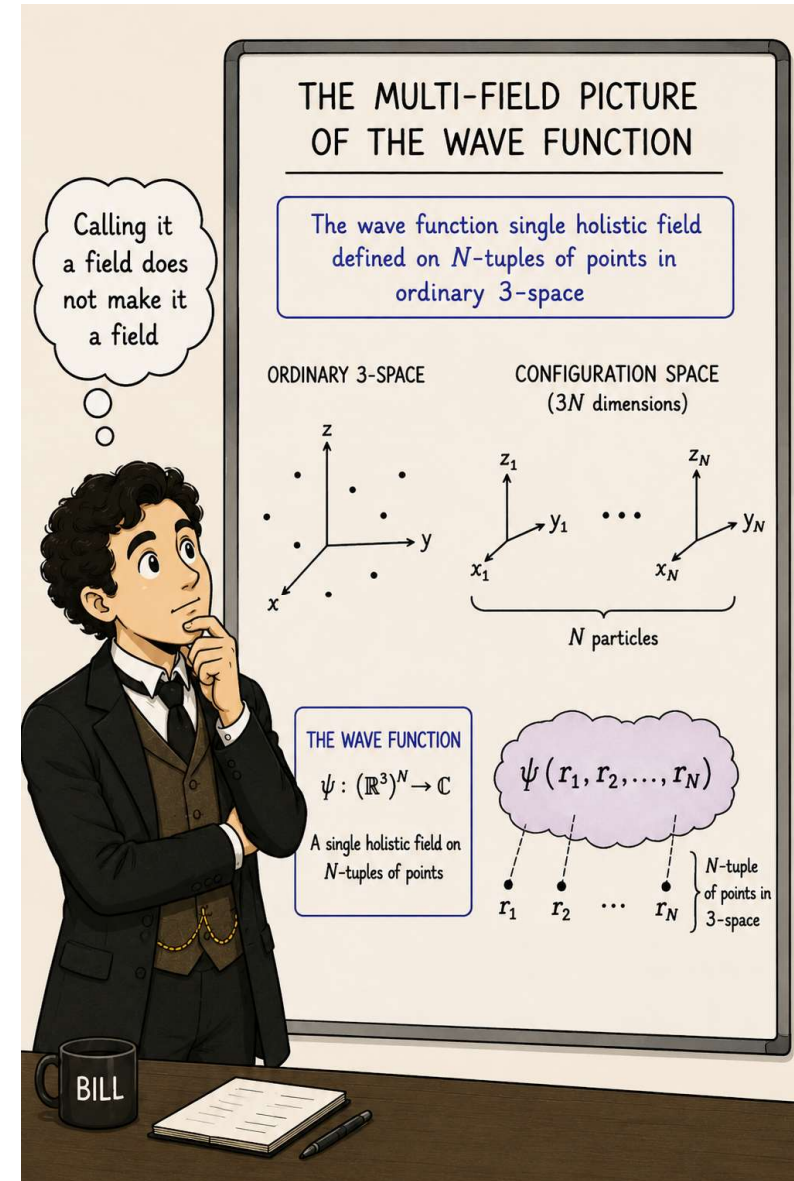


Next: the status of the wave function withing modification 2.C (dBB)

But at least for my proposal things will generalize to non-linear stochastic wf evolutions

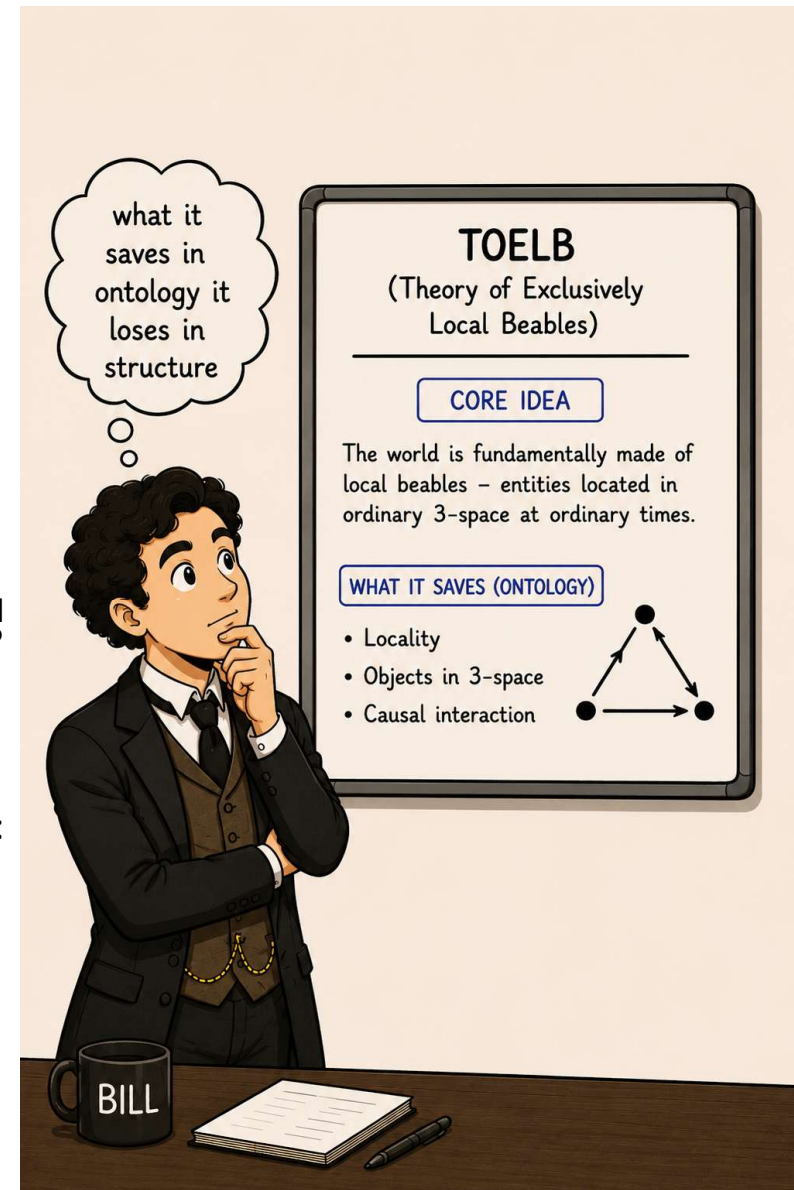
What the wf could be in dBB: multi-field

- In dBB we have particles in 3d, the wf could be seen as **a physical entity in space evolving in time**:
- [PROPOSAL 1: THE wave function as a multi-field](#) (Forrest, Hubert and Romano)
 - The wave function **single holistic field defined on N-tuples of points in ordinary 3-space**
- However: Bill's verdict:** *"Calling it a field does not make it a field; the multi-field keeps the label 'field' while abandoning what makes fields explanatory"*
- 1. It violates the rationale for introducing fields**
- Historically, fields were introduced because they provide a local mediator of interactions
 - They live on spacetime; they have values at points; they propagate; they carry energy and momentum; they mediate interactions
- The multi-field does none of this. It does **not**:
 - propagate from place to place; transmit influences locally; carry energy in the ordinary sense; explain interaction through local mechanisms
- 2. It is not really wave-like**
- Ordinary fields support: oscillations; propagation; interference patterns in physical space
- The multi-field is called a wave because it derives from the wavefunction, but it is not obviously a wave in the ordinary physical sense



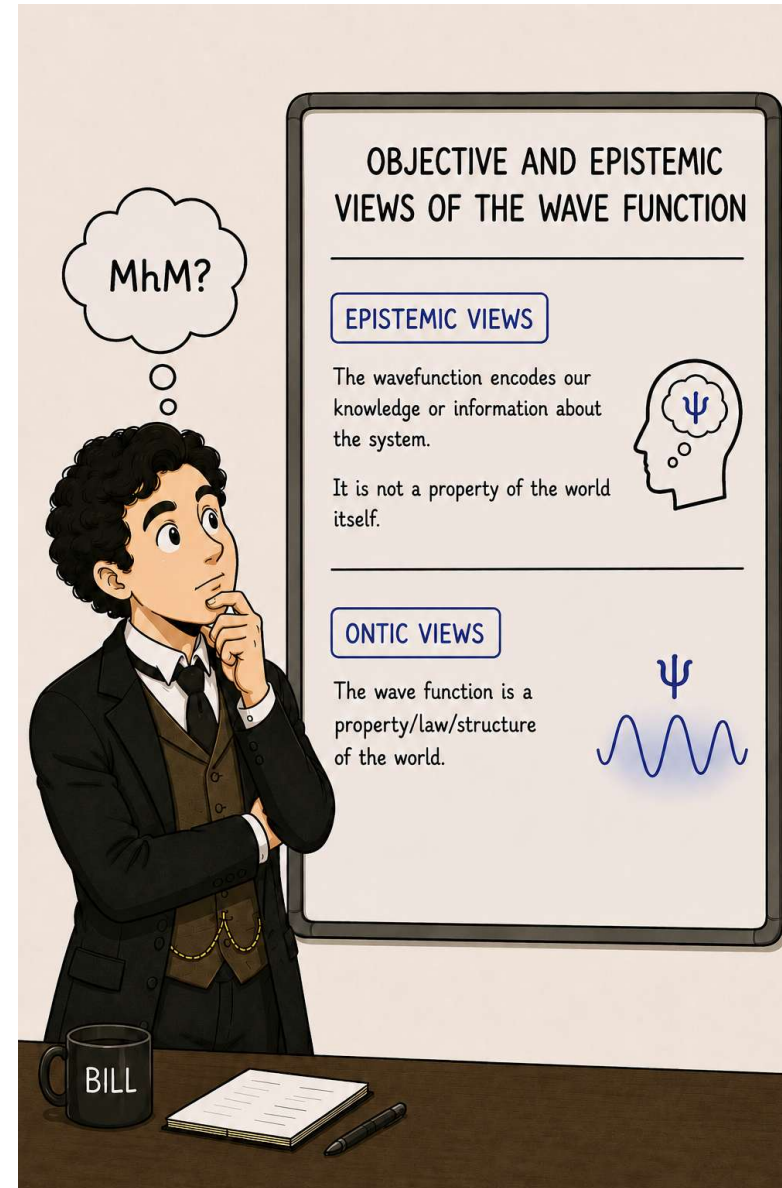
What the wf could be in dBB: TOELB

- PROPOSAL 2- rewrite the theory as to substitute the wf with some other local field or sum of fields (Norsen's Theory of Exclusively Local Beables)
- **However:**
- **1. Ontological proliferation**
 - The motivation is to get rid of configuration space. But the cost is introducing: conditional wavefunctions, entanglement fields, higher-order auxiliary fields, potentially an infinite hierarchy
- **2. Explanatory bookkeeping**
 - The auxiliary fields are introduced because the theory must recover the effects of the universal wavefunction. But are these fields independently motivated physical structures, or bookkeeping devices for information that was already present in ψ ?
- Bill: "The auxiliary fields seem designed to recover the universal wavefunction rather than explain it"
- **3. Loss of theoretical elegance**
 - In "standard" dBB, one has particles and one universal wf. Here we have: particles, many local fields, an elaborate hierarchy
- Bill: "What is saved in ontology may be lost in structure"
- **4. Local beables, nonlocal dynamics**
 - The theory advertises itself as a theory of local beables (spatiotemporally localized entities). Yet the auxiliary fields must encode entanglement information and reproduce Bell-type nonlocality
- Bill: "The local beables are local; the explanation is not"



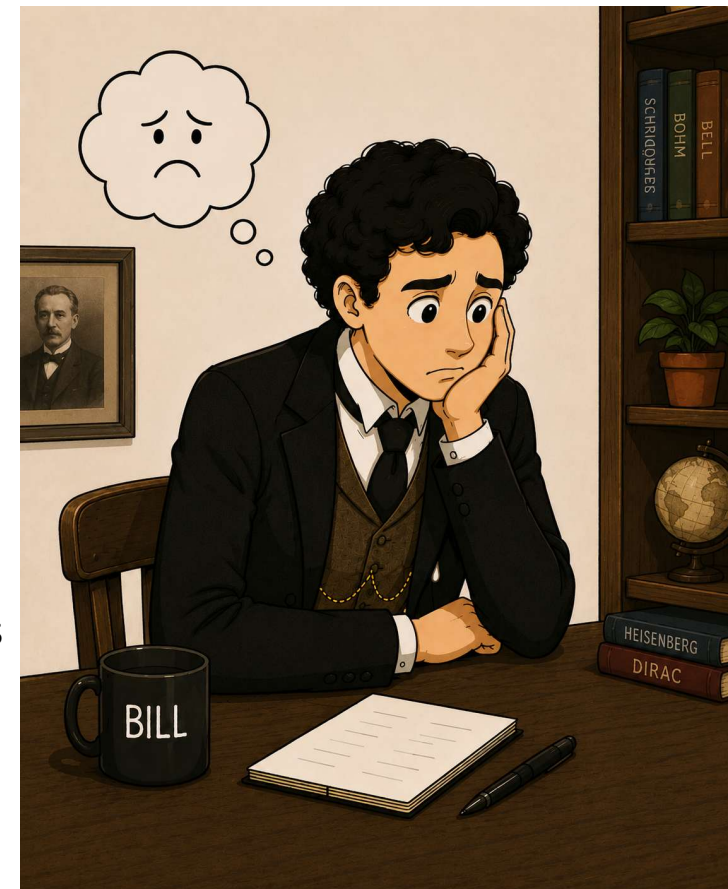
What the wf could be in general, if not a physical field?

- TYPE 1 ATTEMPTS:
 - Ontic (BUT non-material) views of the wf
 - Weak and strong nomological views
- TYPE 2 ATTEMPTS:
 - Epistemic views of the wf
 - Pragmatic, information-theoretic views



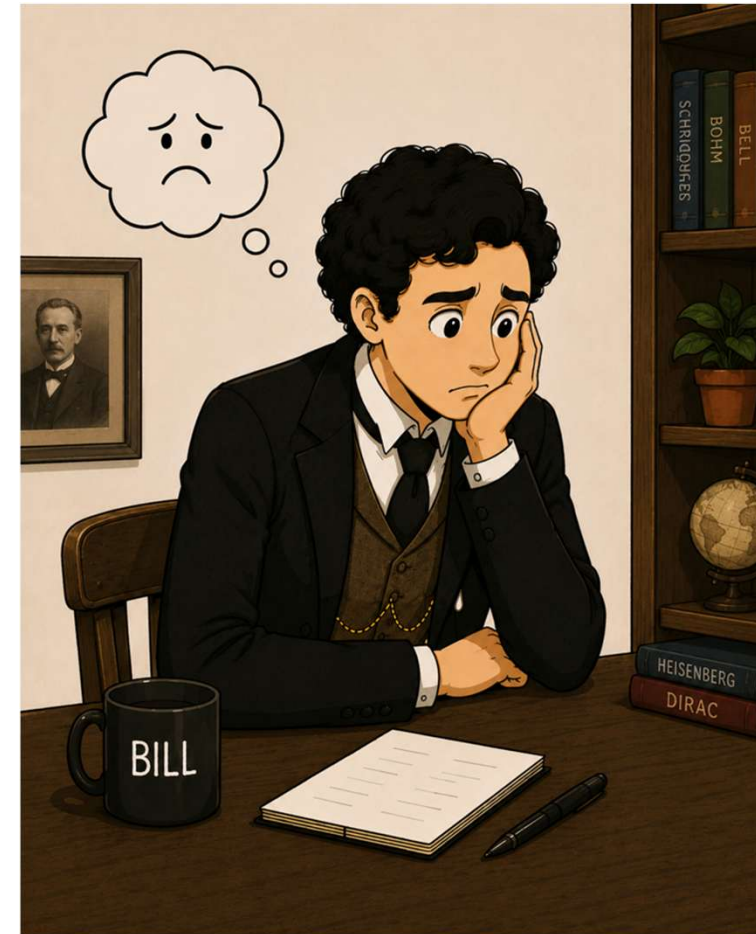
Weak nomological views

- **Some varieties:**
 - **Dispositionalism:** the wave function is a dispositional property (Monton, Esfeld, Suarez, Gao...)
 - **Bill's verdict:** *"You have replaced the mystery of the wave function with the mystery of dispositions"*
 - What exactly is a disposition, and how does it act?
 - **Spacetime state realism:** the wave function (density matrix) is a property of spacetime containing all the relevant dynamical information (Wallace and Timpson)
 - **Bill's verdict:** *"You have moved the quantum state closer to spacetime without making it more explanatory"*
 - Dynamical information attached to spacetime, but properties of spacetime remain unexplained theoretical posits
 - **Structuralism:** the wave function some sort of structure (Esfeld, PJ Lewis ...)
 - **Bill's verdict:** *"You have kept the relations and lost the relata"*
 - Captures what survives theory change, but structure without objects it is explanatorily incomplete



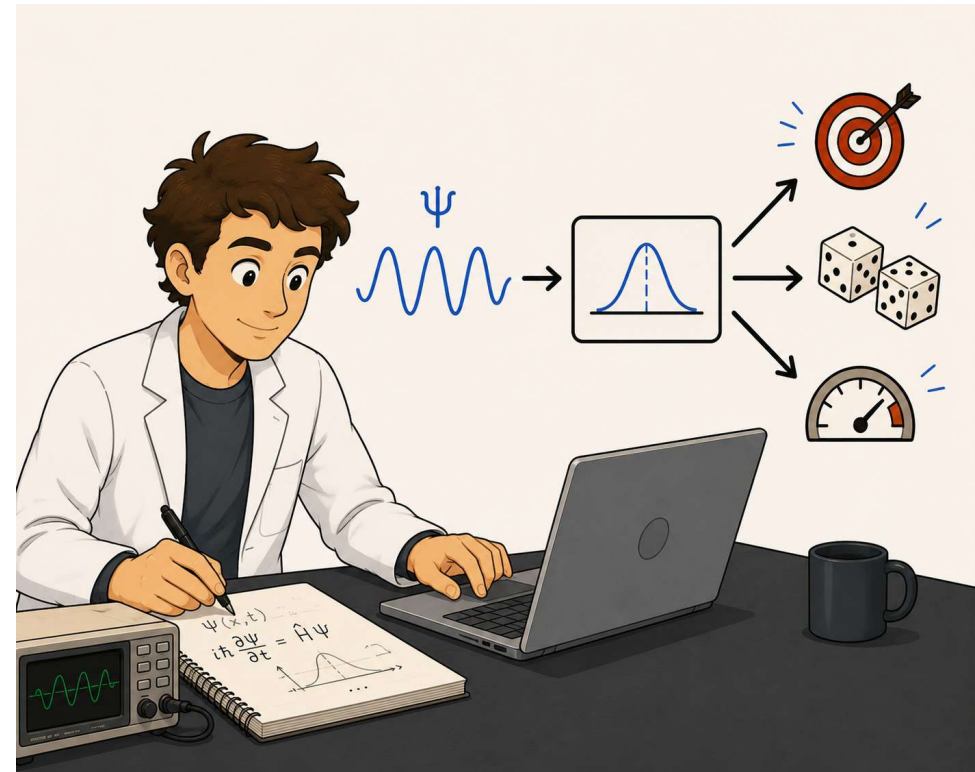
Strong nomological views

- The **wf is a law of nature** (Goldstein and Zanghi; Humean versions: Callender, Miller, Esfeld, Bhogal and Perry,...)
- Good things:
 - Same as the weak view but no account of properties needed
- Bad things:
 - Non-uniqueness: laws of nature are unique, the wf is not
 - Time-dependence: laws do not evolve in time, the wf does
- **Bill's verdict:** *"You call it a law, but it acts like a dynamical variable"*



Epistemic approaches

- Some varieties:
 - **Pragmatist** approaches – Healey
 - **Relational** approaches - Rovelli
 - **Information-theoretic** approaches – Bub and Pitowsky
 - **QBism** - Fuchs
- They all share a **pragmatic** component:
 - The wave function is a **tool** which allows the theory to ‘explain’ the phenomena, and make new predictions
 - It has to do with our knowledge of the system rather than the system itself

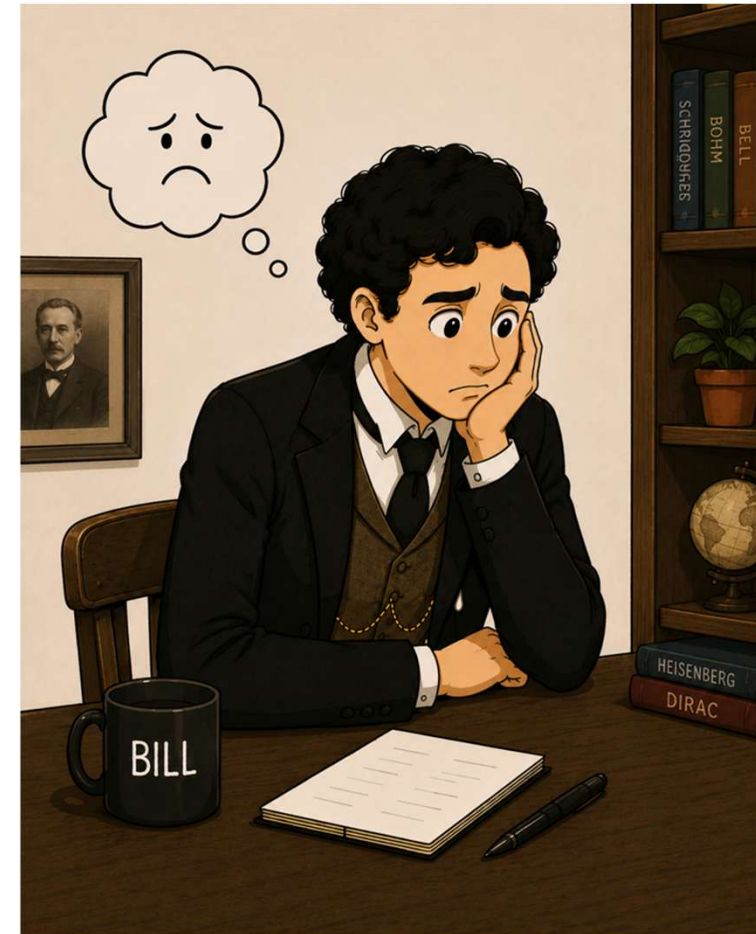


Epistemic approaches

- **Epistemic pragmatist view of the wave function (Healey):**
 - The wf *prescribes how our epistemic attitudes* towards claims about physical situations should be: the wf gives probabilities, which prescribe what the experimenter should believe
 - Pragmatic view: concerns about *explanation* are prior to representational ones: the wf is not some entity to 'reify' or materialize, rather it is something that *allows the theory to be explanatory*
- **Information-theoretic approach (Bub and Pitowsky):**
 - Quantum mechanics is fundamentally about *measurement outcomes*, whose statistics are recovered by the constraints that Hilbert space structure imposes on the quantum dynamics
 - the wf has the role of *describing an agent's preferences* (or expectations or degrees of belief) about measurement outcomes

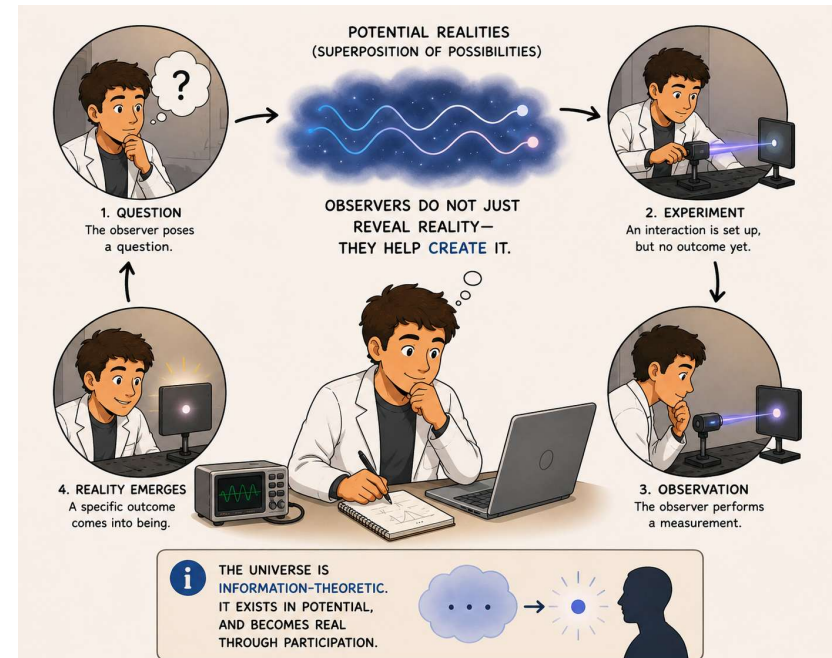
Epistemic approaches

- Good things:
 - They avoid reifying the wave function
 - They naturally explain probability assignments
- Bad things:
 - 1- Experimental **outcomes** (e.g. interference) nonetheless happen, regardless whether anybody possesses knowledge about them
 - **Bill's verdict:** *"You have turned quantum mechanics into a theory about us rather than a theory about the world"*
 - 2- **Information** is always information about something
 - **Bill's verdict:** *"Knowledge presupposes a world to be known"*



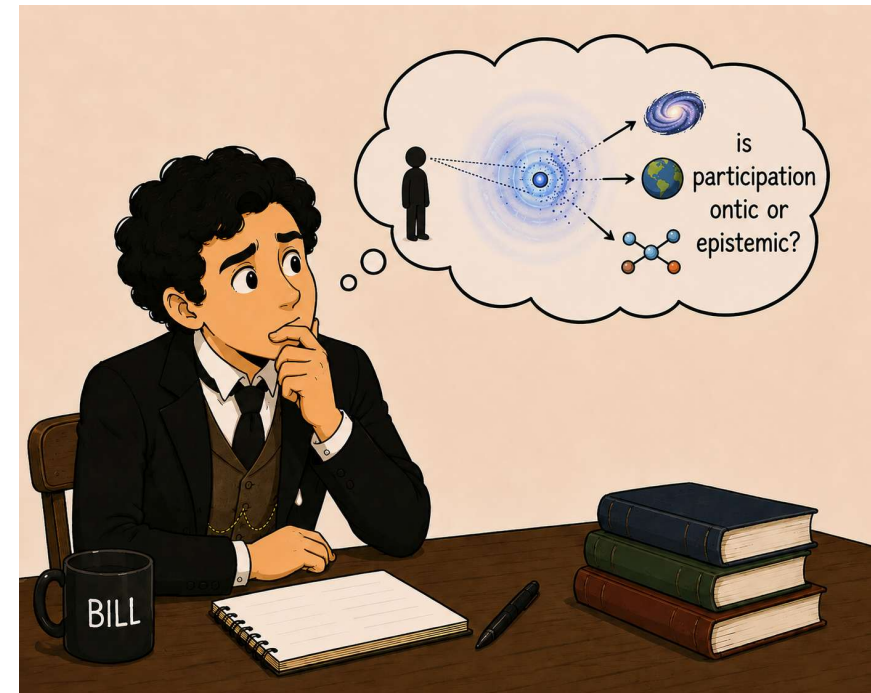
Beyond Epistemicism: The Participatory Turn

- Epistemic approaches may be too weak because they make ψ a tool of knowledge
- Yet they draw attention to an important fact: quantum mechanics seems to place **observers and measurement at center stage**
 - quantum theory is deeply connected to observation
 - measurement matters
 - knowledge is constrained by experimental contexts
- But what should one conclude from that? What exactly does quantum mechanics force us to revise?
 - Reality? Knowledge? Both? Neither?
- The idea of the centrality of measurement has recently re-emerged under the label of participatory realism
- **Participatory Realism** (Wheeler, Qbism, Dieks...)
 - Reality is not fully independent of agents
 - Observers participate in the production of facts



Participatory Realism and Dealism

- Classical physics assumed:
 - Reality \rightarrow Knowledge
- Quantum mechanics suggests:
 - (Reality \leftrightarrow Participation) \rightarrow Knowledge
- Participatory Realism is attractive because it straightforwardly **embraces the centrality of measurement** in QM:
 - Observers are part of reality's constitution
- But is this the lesson?
 - Bill: *“What if QM is not telling us that reality depends on participation? **What if it is telling us that knowledge does?**”*



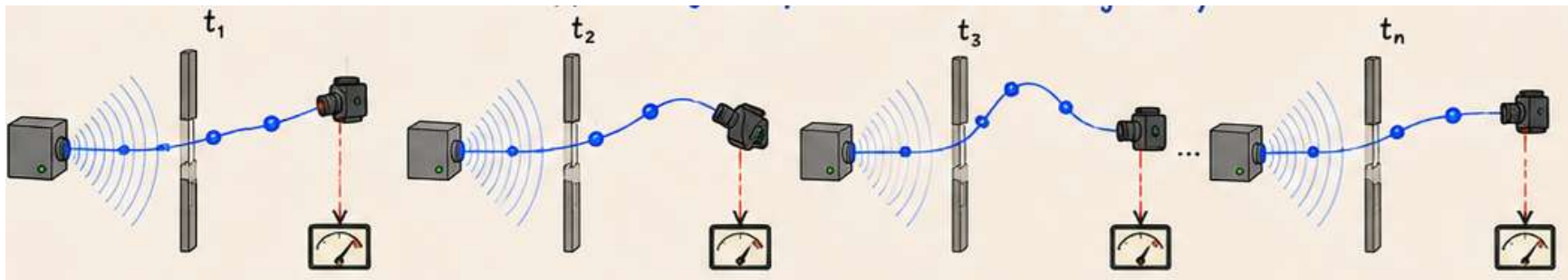
Quantum Limits on Knowledge

• Bohmian Example

- Particles have positions, trajectories exist, yet we cannot generally know them
- **What happens if you try to 'measure' the trajectory?**
 - Suppose you repeatedly 'measure' the position of a Bohmian particle at times t_1, t_2, t_3, \dots
 - Each 'measurement' entangles the particle with the apparatus, changes the effective wave function, alters the guidance equation
 - So, the trajectory after the first 'measurement' is generally **not the same trajectory that would have occurred had you not measured**
 - Thus, the sequence of 'measured' positions does not reveal the "unperturbed" Bohmian path because the observation itself perturbs the motion

• Quantum Mechanics and Epistemic Humility:

- The world may be determinate, but our access to it is not
- Reality exceeds accessibility; what exists and what can be measured (known) are different
- Bill: *"There are intrinsic limits to what we can actually know"*



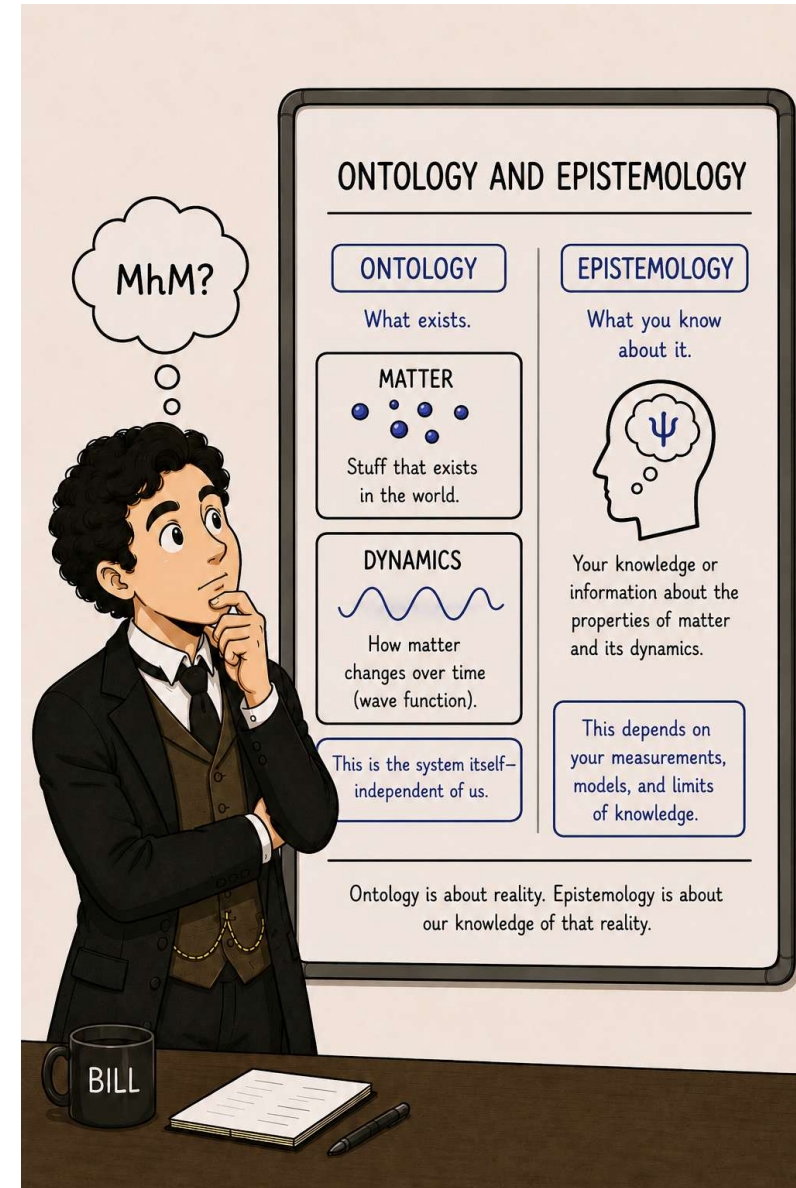
Contextuality and Participation

- Measurement outcomes depend on:
 - System, apparatus, interaction
- knowledge is inherently relational
- However, *reality need not be!*
- **Participation Reinterpreted**
 - Participation enters at the level of *inquiry*, not necessarily at the level of ontology
- **Epistemological Participation**
 - To know is to interact, to interact is to affect what can be known
 - And this is unavoidable
- **A Quantum Kantian Moment?** (Not endorsing Kant!)
 - Reality exists independently
 - But access to it is constrained by the conditions of observation



What About ψ ?


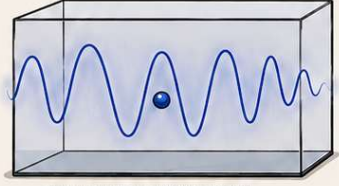

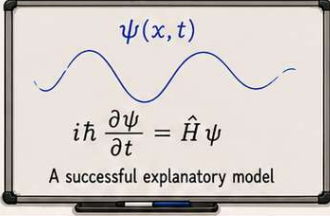

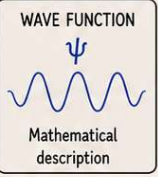







- If knowledge is participatory, how does ψ fit?
- A possible question: “what familiar category does ψ belong to?”
 - Reality itself
 - Information
 - Law
- Wave-Functionalism (the view I wish to discuss) instead asks: “**what explanatory work does ψ perform?**”
- **The Dealist Picture**
 - ONTOLOGY— Matter as a spatiotemporal entity & Wave function as a nomic functional structure
 - EPISTEMOLOGY — Participation, contextuality, limits on knowledge



The Dealist Moral

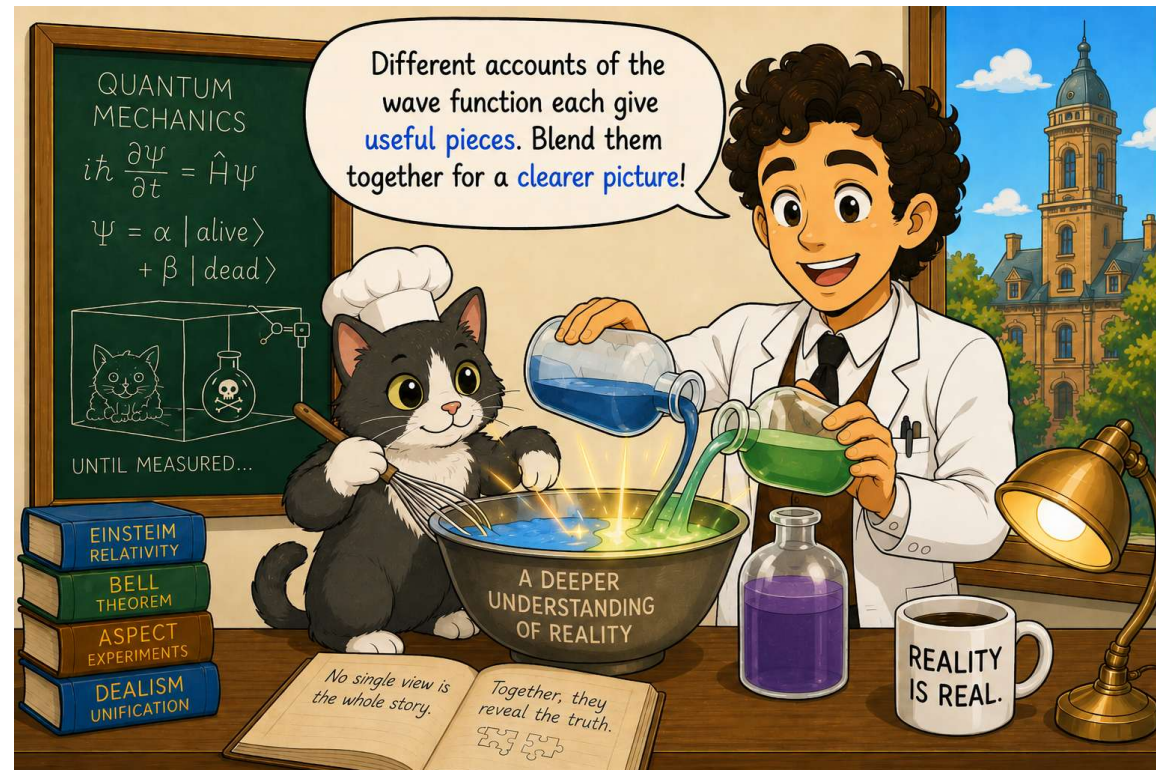
- Bill: "Do not infer ontology from epistemology"
- A limit on knowledge is not automatically a limit on reality
- Final Thesis
 - Quantum mechanics does *not* show that *reality* depends on observers
 - Quantum mechanics shows that *knowledge* depends on participation

WHAT SURVIVES? WHAT BELONGS WHERE?

 <p>REALITY SURVIVES.</p>	<p>Reality exists independently. Matter and its dynamics do not depend on what we know.</p>	 <p>REAL SYSTEM (ONTOLOGY)</p>	
 <p>EXPLANATION SURVIVES.</p>	<p>Our explanations and models also survive. Science builds models that remain valid even if they are imperfect.</p>	 <p>A successful explanatory model</p>	
 <p>THE WAVE FUNCTION IS NOT MATTER.</p>	<p>The wave function is a mathematical description, not a physical thing. It does not occupy space. It does not have mass, energy, or location. It is not made of stuff.</p>	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>WAVE FUNCTION</p>  <p>Mathematical description</p> </div> <div style="font-size: 2em;">≠</div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>MATTER</p>  <p>Physical reality</p> </div> </div>	
 <p>PARTICIPATION BELONGS PRIMARILY TO EPISTEMOLOGY.</p>	<p>Participation is about what we do— not what the world is made of. Our measurements, choices, and interactions are features of our knowledge and information. That belongs to epistemology, not to matter itself.</p>	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>ONTOLOGY (WHAT EXISTS)</p>  <p>Matter & dynamics exist independently</p> </div> <div style="text-align: center;">  <p>EPISTEMOLOGY (WHAT WE KNOW)</p> <p>Observation, measurement, information, participation</p> </div> </div>	
 <p>Reality survives. The world is independent.</p>	 <p>Explanation survives. Good models endure.</p>	<p>$\Psi \neq \bullet$</p> <p>The wave function is not matter. It's a description, not a thing.</p>	 <p>Participation belongs primarily to epistemology. It is about what we know and do.</p>

Towards a better account what the wf is

- Suppose we want to be **dealist about the wf** :
 - the wf is objective (ontic) but it's not representing a material entity
- What are our **options**?
 - Ontic [non-material → nomic] accounts have problems
 - Epistemic approaches are also problematic (and not objective)
- However: maybe we can use **something** in these approaches that might help construct a **better account** of the wf if we do not want to consider the wf as material BUT we want to be dealist about it....



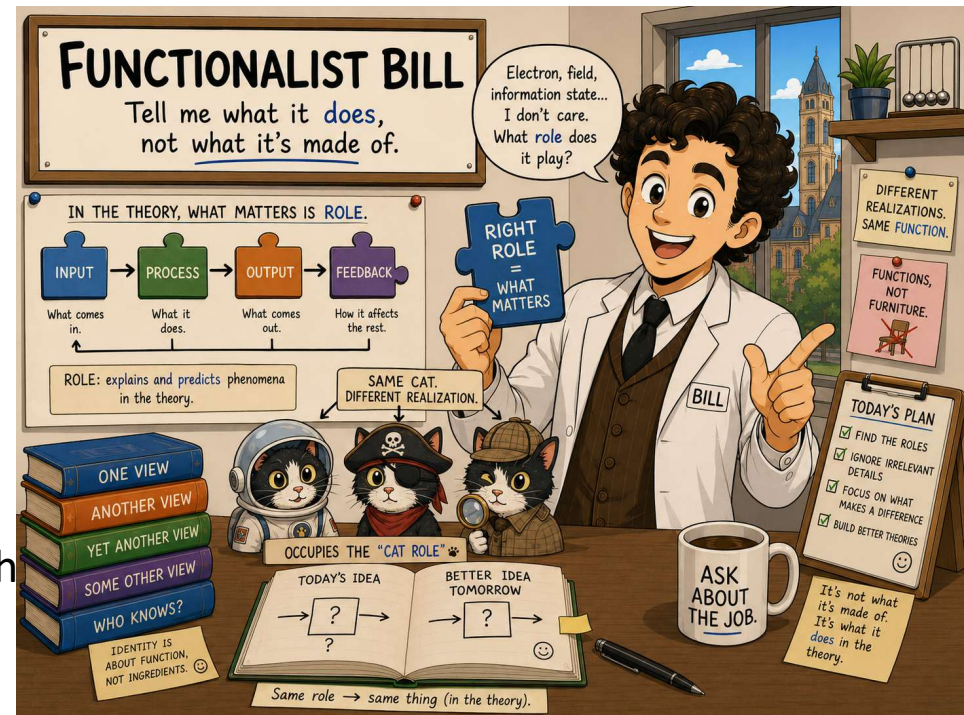
Pragmatism to the rescue?

- The nomological views and the pragmatic view might be seen as agreeing on:
 - The *lack of emphasis in a representational role* of the wf (the wf does not represent something material)
 - The *explanatory role* of the wf
 - The *dispensability* of the wf to the (material) ontology of quantum mechanics



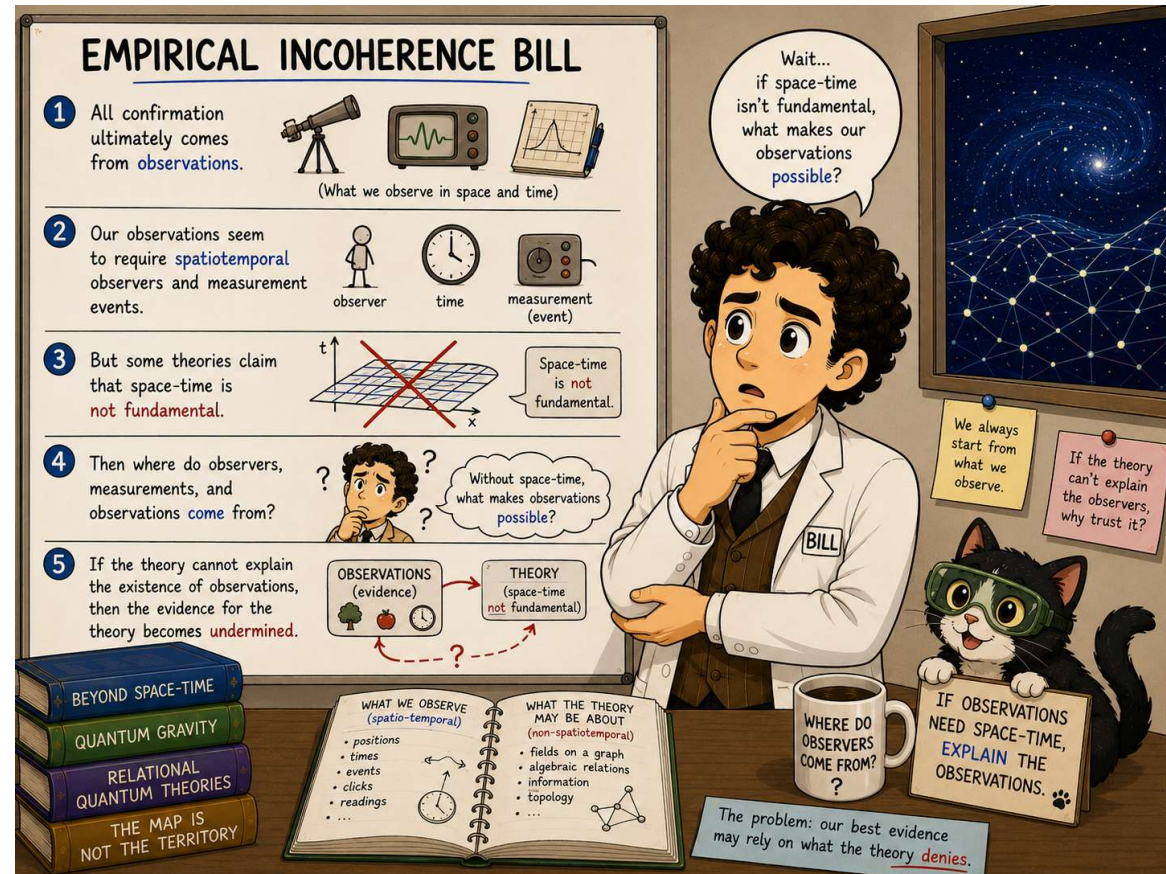
Functionalism to the rescue?

- Functionalism: certain entities can be defined in terms of **their functional role**
 - Functionalism in philosophy of physics
 - Knox: **space-time** can be functionalized in **classical theories** of gravity - an entity is spatiotemporal as determined by its functional role
 - Lam and Wüthrich: **space-time** can be functionalized in **quantum gravity** - space-time can emerge if one recovers those features which are functionally relevant in producing observations
 - Albert: **3-d objects** can be functionalized in quantum mechanics - 3-d objects are determined by their causal roles, and then the wf dynamically gives rise to the empirical evidence



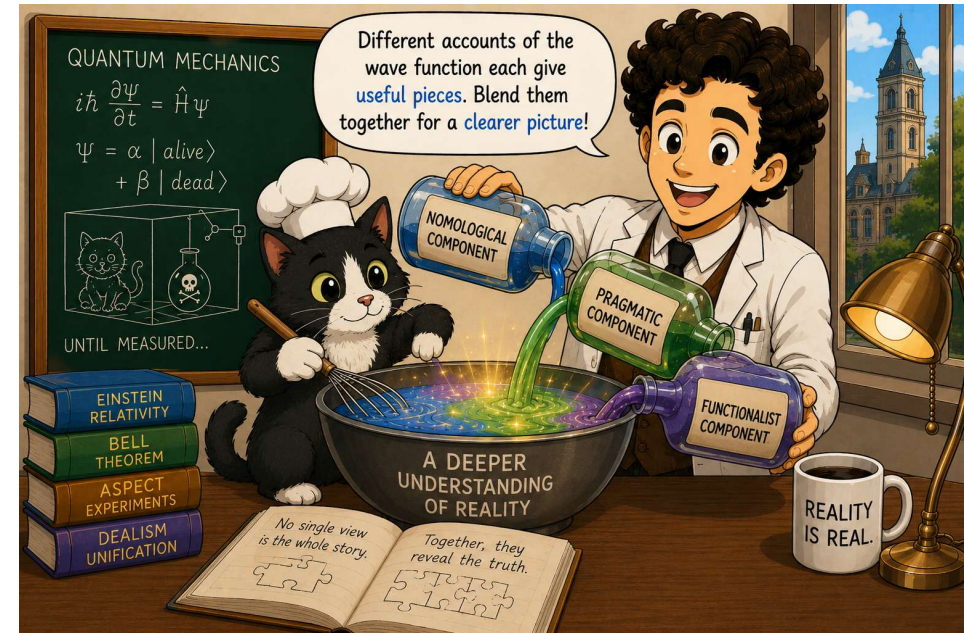
Empirical Incoherence

- Functional approaches (and in general emergentist approaches from a non-spatiotemporal background) are all threatened by the problem of **empirical incoherence**:
 - A theory is empirically incoherent if its truth undermines our empirical justification for believing it



Wave-functionalism: general idea

- “Cherry-pick” ingredients from the various approaches, so as to capture the intuitions that the wf has:
 - a **nomological** component: it is part of the laws of nature as a ‘guiding’ entity
 - a **pragmatic** component: it is explanatory rather than representational, and
 - a **functionalist** component: the wf can be dispensed with by reducing it to its functional role in the theory




In taking from all these approaches in part but not in their totality, one can (perhaps!) avoid the objections to each and every one of the single views taken separately

Nomological Aspect

- The wf is **not** a law of nature, strictly speaking
- Rather it is **part of the law**:
 - it is one of the ingredients that allows the dynamics of matter to be written
 - Being merely an ingredient in the law:
 - the wf does not have to be unique, like potentials are not unique
 - It can be dispensed with:
 - other entities, such as the density matrix, can play its role
 - It does not have to be time-independent

THE NOMOLOGICAL COMPONENT OF THE WAVE FUNCTION

The wave function is **part** of the laws of nature, not the whole story.



The wave function is not the entire law. It is part of the law—like one ingredient in a recipe.

THE LAW (THEORY)

Quantum dynamics law (e.g., Schrödinger equation)


$$i\hbar \frac{\partial}{\partial t} \psi(\mathbf{r}, t) = \hat{H} \psi(\mathbf{r}, t)$$

Structure of change

Wave function (part of the law)

Hamiltonian (energy operator)

Other ingredients: initial conditions, boundary conditions, constants, symmetries, etc.




It's part of the recipe of the laws of nature!

NOT THE WHOLE RECIPE!

A CATEGORY MISTAKE: THE WAVE FUNCTION IS NOT THE LAW ITSELF

❌ CATEGORY MISTAKE

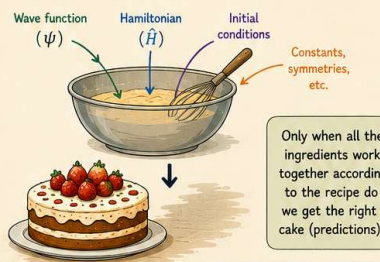
Thinking the wave function **IS** the law is like thinking "flour **IS** the recipe."



Flour is an ingredient. The recipe is the set of instructions that tells ingredients what to do. Confusing the two is a category mistake.

✅ THE CORRECT VIEW

The wave function is an ingredient in the law—essential, but not the whole law.



Only when all the ingredients work together according to the recipe do we get the right cake (predictions).

WHY THIS MATTERS (NOMOLOGICAL POINT)

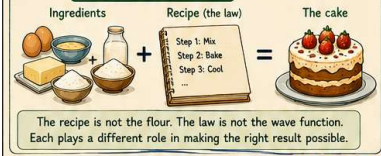
- ✓ The wave function appears in the dynamical law. It helps govern how systems evolve.
- ✓ It is constrained by and interacts with other elements of the law.
- ✓ Remove it (or change its role), and you change the law, not just the world.

The wave function is a "guiding" entity within the law—part of the nomological fabric of nature.

NOT THIS:

- ❌ The wave function is not a hidden object behind the law.
- ❌ The wave function is not identical to the law.
- ❌ The law is more than just the wave function.


BACK TO OUR CAKE



The recipe is not the flour. The law is not the wave function. Each plays a different role in making the right result possible.

NOMOLOGICAL MORAL

- ✓ The wave function is part of the laws of nature as a "guiding" entity.
- ✓ Confusing a part of the law with the whole law is a category mistake.
- ✓ Understanding the roles of the parts is key to understanding the whole.



It's not what the law is made of—it's part of what makes the law work!

★ THE WAVE FUNCTION IS **PART OF THE LAW**, NOT THE WHOLE LAW. IT'S AN INGREDIENT IN NATURE'S RECIPE. ♥

Pragmatic Utility

- The wf is a **useful object** to adequately recover the empirical predictions (the Born rule)
- The wf does not represent matter but **it is explanatory**:
 - Pragmatically, one uses the wf to generate the probability outcomes given by the Born rule, but one could have chosen another object, evolving according to another evolution equation
 - The fact that quantum mechanics is formulated in terms of the wf is contingent to other super-empirical considerations (e.g. simplicity and explanatory power)
- *Contra* epistemic approaches, here the wf has **not** to do with our incomplete knowledge of the system

THE PRAGMATIC COMPONENT OF THE WAVE FUNCTION

The wave function is an explanatory tool, not a picture of reality.



The wave function is like a recipe for a cake: it helps us explain and predict how the cake turns out. It is **not** the cake itself.



WHAT MATTERS PRAGMATICALLY

- It works:** It yields accurate predictions for observations.
- It explains:** It unifies and makes sense of diverse phenomena.
- It is useful:** It guides successful action (experiments, technology).

We value the wave function for what it does for us in practice.

A RECIPE IS EXPLANATORY, NOT REPRESENTATIONAL

NOT A PICTURE OF THE CAKE	AN EXPLANATORY TOOL
 <p>The recipe is not a mental image or a copy of the cake.</p>	 <p>The recipe explains and predicts even though it is not the cake.</p>



The recipe earns its keep by helping us bake great cakes!

THE PRAGMATIC POINT

What matters is not the **intrinsic** nature of each ingredient, but the **role** it plays in making the cake turn out right.

↓

The recipe is valuable because it works!

PRAGMATIC MORAL

We are pragmatists about the wave function.

- ✓ We do **not** require the wave function to be a literal description of reality.
- ✓ We value it because it explains, predicts, and guides successful practice.
- ✓ As long as it continues to do this better than alternatives, we should keep using it.
- ✓ If a better tool comes along that does the job even more powerfully, we should be open to using that instead.

In short: the wave function is an explanatory tool, and that is enough.



We don't eat recipes. But without good recipes, we wouldn't bake such amazing cakes!


Good theories are tools for understanding and success, not pictures of the world.

Functional Multiple Realizability

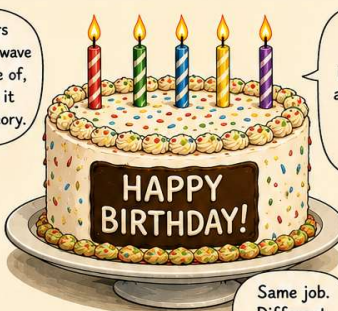
- A function is not identical to any particular realization
- Different physical structures can realize the same function -- the wf is like that
- Es: functions of the wf:
 - Generate Born-rule probabilities
 - Contribute to the dynamics
 - Connect theory and evidence
- They can be realized in different ways: wf, density matrix, etc....
- The wave function is *one possible* realization of the functions needed to recover the empirical predictions
- What matters is not the physical nature of the realize, but the role it plays in the theory
- **Bill's slogan:** “The wave function is as the wave function does”

WAVE-FUNCTION FUNCTIONALISM


The wave function is like the **role structure** of a recipe.








What matters is not what the wave function is made of, but what role it plays in the theory.








It doesn't matter which specific ingredients you use, as long as each plays its role correctly, the cake turns out just right!



Same job. Different ingredients.


INGREDIENTS AND THEIR ROLES (IN THE CAKE)				
EGG  Role: agglomerate ingredients, give structure.	MILK  Role: add moisture, make the batter smooth.	SUGAR  Role: make it tasty, help with browning.	BUTTER  Role: add richness, softness, flavor.	FLOUR  Role: provide structure, give body to the cake.

THEY CAN BE SUBSTITUTED! (MULTIPLE REALIZABILITY)				
EGG  ↓ FLAX EGG (or applesauce, or mashed banana)	MILK  ↓ SOY MILK (or almond milk, or oat milk)	SUGAR  ↓ HONEY (or maple syrup, or agave)	BUTTER  ↓ MARGARINE (or coconut oil, or olive oil)	FLOUR  ↓ ALMOND FLOUR (or oat flour, or rice flour)

Different physical ingredients can realize the same roles and produce the same kind of cake.

FUNCTIONALIST MORAL

- Eggs can differ physically.
- Milk can differ physically.
- Sugar can differ physically.
- Butter can differ physically.
- Flour can differ physically.




- Fields
- Information structures
- Laws
- Mathematical objects
- ... and more

Yet the same cake function can be realized.


Same role in the theory. Same function. That's what matters.

★ Functionalism is about roles in the theory, not the underlying physical makeup.



Different realizations can play the same wave-function role in the theory.

A useful distinction



Not everything in a theory does the same job! Some do the heavy lifting, others just help make the recipe possible.

EXPLANATIONISM


> (KITCHER, PSILLOS) <

Explanationism tells us what kinds of theoretical posits are responsible for a theory's success.

A THEORY CONTAINS TWO KINDS OF POSITS

THEORY

- ✓ Equations
- ✓ Concepts
- ✓ Models
- ✓ Principles
- ✓ ...




Think of a recipe for a cake: some things do the real explanatory work, others just help make it possible!

1. WORKING POSITS

Responsible for the theory's explanatory success. They survive theory change.

THEY DO THE HEAVY LIFTING!




- Explain why the cake rises and holds shape (flour, eggs)
- Explain why it tastes sweet (sugar)
- Explain why it bakes the right way (heat)

If you remove these, the cake (the explanations) fails. These are the posits we want to keep because they do the explanatory work.

2. PRESUPPOSITIONAL POSITS

Useful theoretical ingredients: they help the theory work, but may disappear without loss of explanatory power.

THEY MAKE THE RECIPE POSSIBLE!



- The mixing bowl
- The whisk
- The measuring cups
- The recipe format
- The language we use ("mix", "bake", "soft")
- ...

We could replace these with different tools or formats and still make the same cake. They are helpful, but not responsible for success.

WAVE-FUNCTIONALISM

The wave function is best understood as a **PRESUPPOSITIONAL POSIT**.

WORKING POSITS
(explanatory core)

- Hamiltonian
- Symmetries
- Interaction laws
- Conservation laws
- ...


WAVE FUNCTION (ψ)
(presuppositional)

- Essential for formulating the theory
- Helps compute and organize predictions
- Not part of the ontology of matter

EXPLANATORY SUCCESS

- Accurate predictions
- Novel phenomena
- Unified understanding
- Technological power
- ...


ψ is indispensable in the recipe of quantum theory, but it's not one of the ingredients in the cake itself (matter).




So the success of quantum theory doesn't force us to be realists about ψ !

BILL'S SLOGAN:

"THE SUCCESS OF QUANTUM THEORY DOES NOT FORCE REALISM ABOUT ψ ."






Just the right role, not the wrong metaphysics!

THE BIG PICTURE


- ✓ Explanationism: keep what earns its keep.
- ✓ Presuppositional posits are indispensable for theory construction, but not part of the ontology.
- ✓ Wave-functionalism respects the success of quantum theory without committing to realism about ψ .



Matter vs Interaction


WAVE-FUNCTIONALISM AND MATTER


What's real? What does the wave function do?



Let's be clear about what the wave function is—and what it is not!

BIG IDEA:

The ontology of matter and the structure governing matter should not be conflated. 




The wave function is about how matter behaves together, not what matter is made of!


1 WHAT IS MATTER?

In our view, matter is made of local beables—things that exist in space and time.


EXAMPLES OF MATTER (ONTOLOGY)




Particles
(point-like entities)



Flashes
(events in space-time)



Mass-density
(distributed matter)



Other local beables
(e.g. fields, primitive ontology)

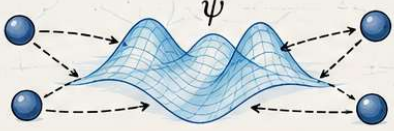
These are the things that are **real**—the stuff of the world.

2 WHAT THE WAVE FUNCTION DOES

The wave function **does not represent matter**. Instead, it **characterizes the interaction of matter**.

HOW TO THINK ABOUT IT

The wave function tells us how the bits of matter influence each other and jointly evolve.



It encodes patterns of correlations, constraints, and dynamics among the beables.

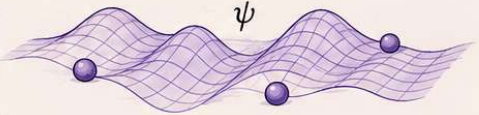
→ Wave function = **rule of interaction**, not stuff.

3 OTHER APPROACHES: NOT LIKE THIS


Other views treat the wave function as if it were a thing in the world—on the same ontological level as matter. **We don't.**

EXAMPLE: WAVE FUNCTION REALISM

The wave function is a real physical object (or field) that exists in space-time.




- ✗ Treats ψ as part of the ontology.
- ✗ Conflates the structure governing matter (with ψ) with matter itself.




So the wave function is essential—but not what the world is made of.

BILL'S SLOGAN:


“The ontology of matter and the structure governing matter should **not** be conflated.”





Different jobs, different things!

- ✓ Matter = what there is.
- ✓ Wave function = how it all works together.
- ✓ Don't mistake the recipe for the ingredients!



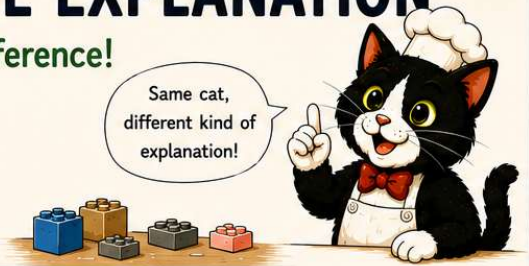
Different Explanatory Strategies

PRINCIPLE vs. CONSTRUCTIVE EXPLANATION

Bill builds a cat to show the difference!



TWO KINDS OF EXPLANATION
We can explain how the LEGO cat exists in two different ways.



1 PRINCIPLE-STYLE EXPLANATION (Why it should be expected)

Focus: principles, expectations, constraints

Principle theories do not answer “why” questions.
They answer: “Why should this be expected?”

PRAGMATIC APPROACHES

- Explain expectations
- Explain probabilities
- Explain constraints on phenomena

➔ Principle-style explanation: principles constrain what is possible and what is expected.



➔ We appeal to general principles and laws to explain the patterns, regularities and probabilities we observe.

EXAMPLES

- Stability comes from balance and support.
- Connections transmit forces.
- Probabilities constrain likely outcomes.
- Physical laws limit what can happen.

2 CONSTRUCTIVE-STYLE EXPLANATION (Why it is the way it is)

Focus: mechanisms, composition, dynamics

Constructive theories answer “why” questions.
They explain: “Why is this the way it is?”

WAVE-FUNCTIONALISM

- Explains trajectories of spatiotemporal entities
- Explains observed outcomes (Lego-style)
- Explains statistics through matter dynamics

➔ Constructive-style explanation: macro stuff is composed of micro stuff; macro laws are derived from micro dynamics.



EXPLAINED BY:
 Particular steps and operations
 Parts and their arrangements
 Interactions over time
 =
 The whole cat!

➔ We explain the cat by showing the actual construction history—the parts, steps, and interactions that make it what it is.

EXAMPLES

- Build the body.
- Add the legs.
- Attach the head.
- Add the ears, nose, whiskers.
- Finish the tail!

KEY DIFFERENCE

They answer different questions.

PRINCIPLE-STYLE EXPLANATION

Answers: Why should this be expected?
(Not: Why is this the way it is?)

Focus: General principles, constraints, laws



Outcome: Explains and limits possible phenomena

CONSTRUCTIVE-STYLE EXPLANATION

Answers: Why is this the way it is?
(Not: How does this happen?)

Focus: Mechanisms, composition, dynamics



Outcome: Builds up the phenomenon from the bottom up



“The ontology of matter and the structure governing matter should not be conflated.” ❤️



TWO WAYS OF EXPLAINING WHY REGULARITIES APPEAR

Principle-type vs. Constructive (compositional) explanations



Let's see two different ways to explain why patterns show up in the world!



Both explanations can tell us that the LEGO cat exists and behaves in certain regular ways. But they do it differently!

Same cat, different kind of explanation!



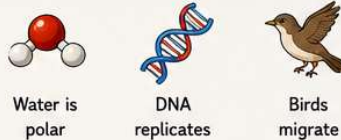
1 PRINCIPLE-TYPE (OR STRUCTURAL/PURELY FUNCTIONAL) EXPLANATION

They explain why a given regularity (ontological or dynamical) appears at a given scale.

HOW IT WORKS

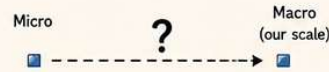
- Identifies general principles, symmetries, constraints or laws that govern a level.
- Shows that the regularity follows from those principles.

E.G.: CHEMISTRY, BIOLOGY, ZOOLOGY



KEY FEATURES

- Works at the level of the system or scale considered.
- Does not look inside to lower-level mechanisms.
- Answers: Why should this regularity be expected here?



➔ It tells us the **rule of the game** at this scale, but not why the rules work.

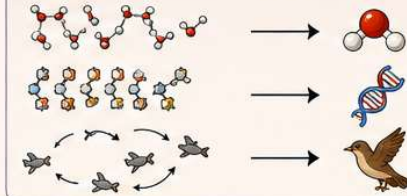
2 CONSTRUCTIVE (COMPOSITIONAL) EXPLANATION

They ALSO explain why that regularity appears in terms of what happens at the microscopic level.

HOW IT WORKS

- Starts from the micro-level parts and their interactions.
- Shows how, step by step, they give rise to the higher-level regularity.
- Explains why the principle holds by deriving it from what really happens below.

E.G.: CHEMISTRY, BIOLOGY, ZOOLOGY



KEY FEATURES

- Goes down to the microscopic level.
- Builds the higher-level regularity from microscopic entities and dynamics.
- Answers: Why does this regularity appear in terms of what happens at the micro-level?



➔ It builds the bridge from micro to macro and explains why the higher-level pattern emerges.



So which one has more explanatory power?

BILL'S VERDICT:
Constructive theories have greater explanatory power because they can account for **why** principles hold at different scales.

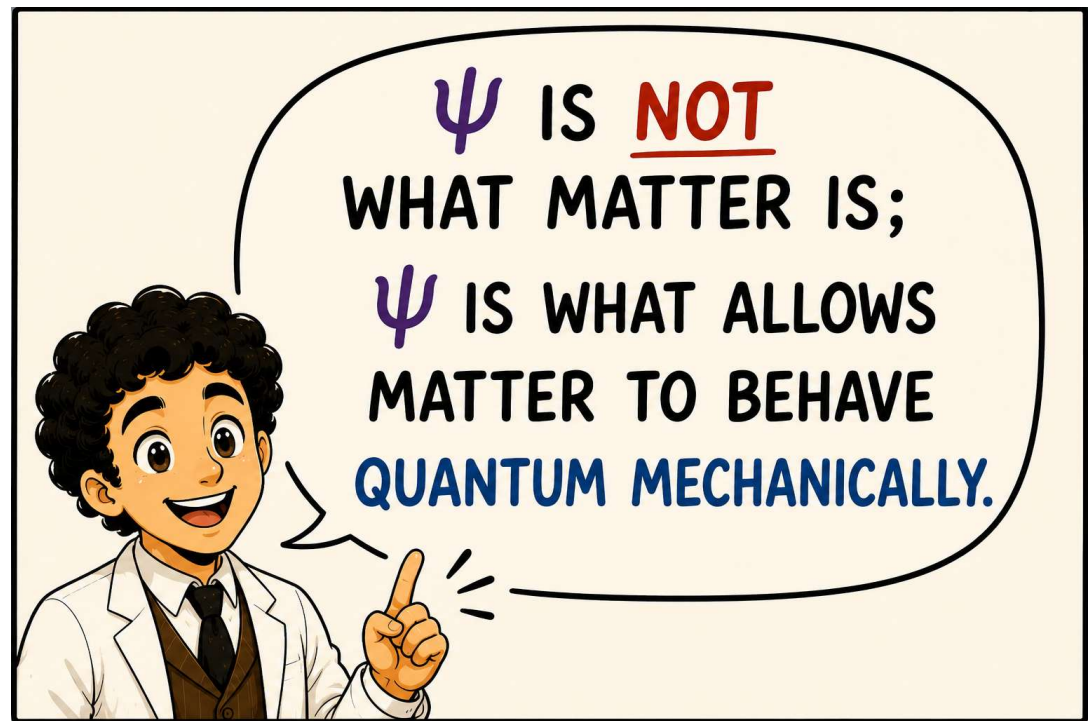


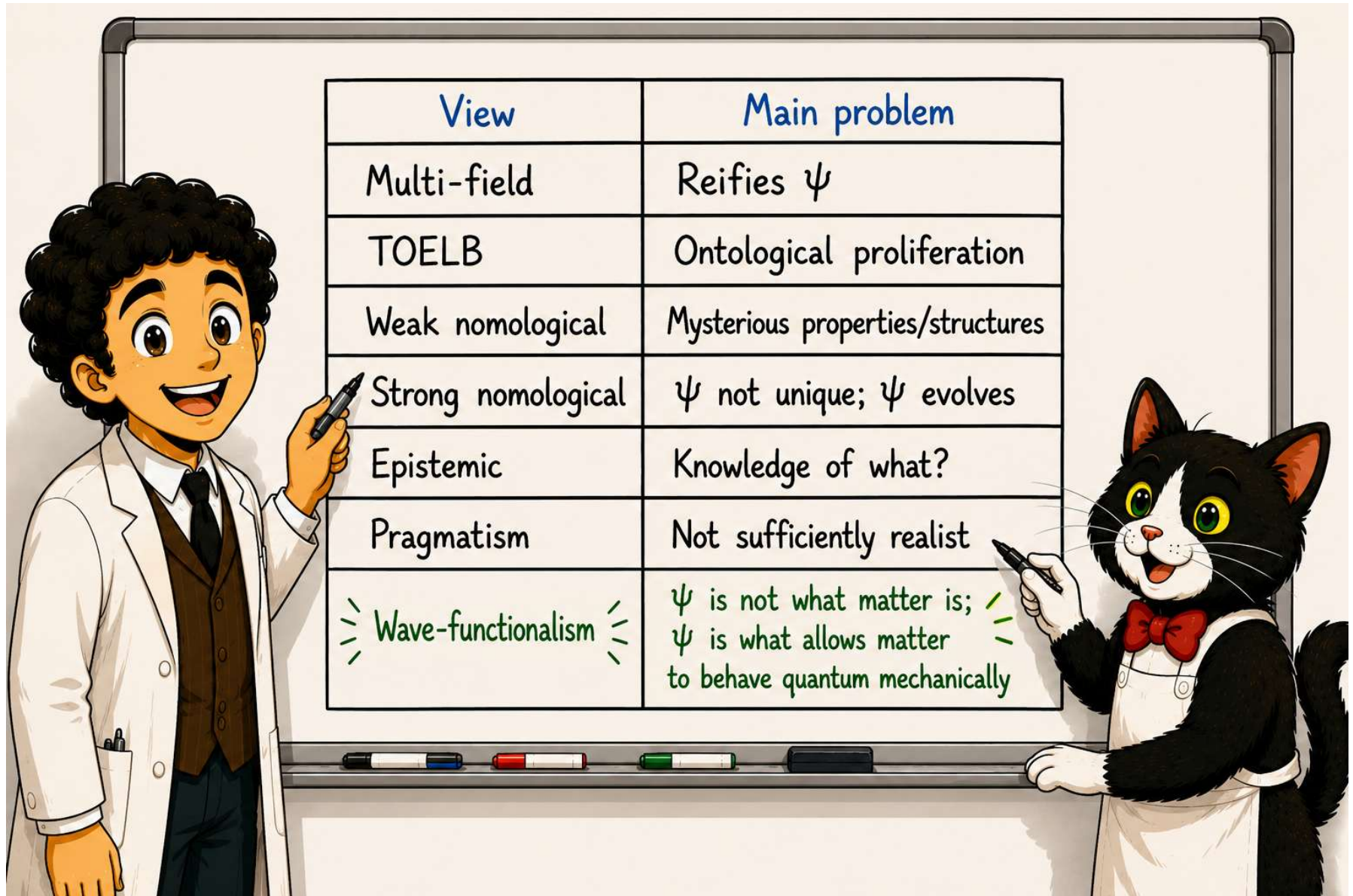
Principles tell us what to expect. Constructive explanations tell us why it happens!

Why prefer wave-functionalism?

If you are a Dealist,
Wave-functionalism is
the natural option:

- Objective
- Non-material
- Non-representational
- Constructively explanatory





View	Main problem
Multi-field	Reifies ψ
TOELB	Ontological proliferation
Weak nomological	Mysterious properties/structures
Strong nomological	ψ not unique; ψ evolves
Epistemic	Knowledge of what?
Pragmatism	Not sufficiently realist
Wave-functionalism	ψ is not what matter is; ψ is what allows matter to behave quantum mechanically

Conclusion

- Wave-functionalism:
 - a view in which the wf is best seen as **non-representational** but as an **explanatory** entity that can be **functionalized** in virtue of its **nomological** role
- Perhaps Bill will like it:
 - It fares a little better than the main alternative view in this camp (= the nomological view; weak or strong)
 - And that it is the natural choice for the Dealist



Thank you for your attention!

