Why is there no consensus on the foundations of quantum mechanics?

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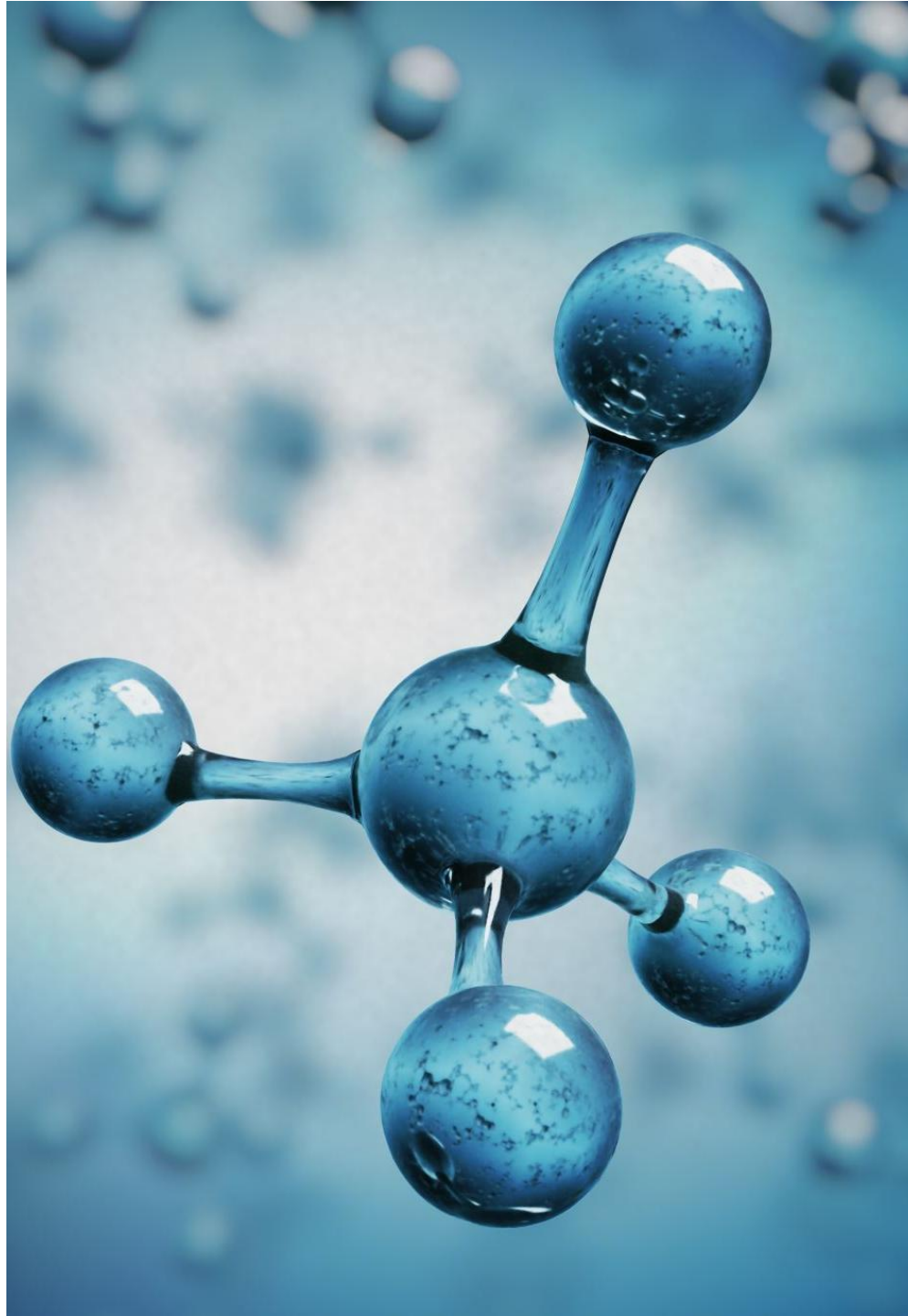
Outline

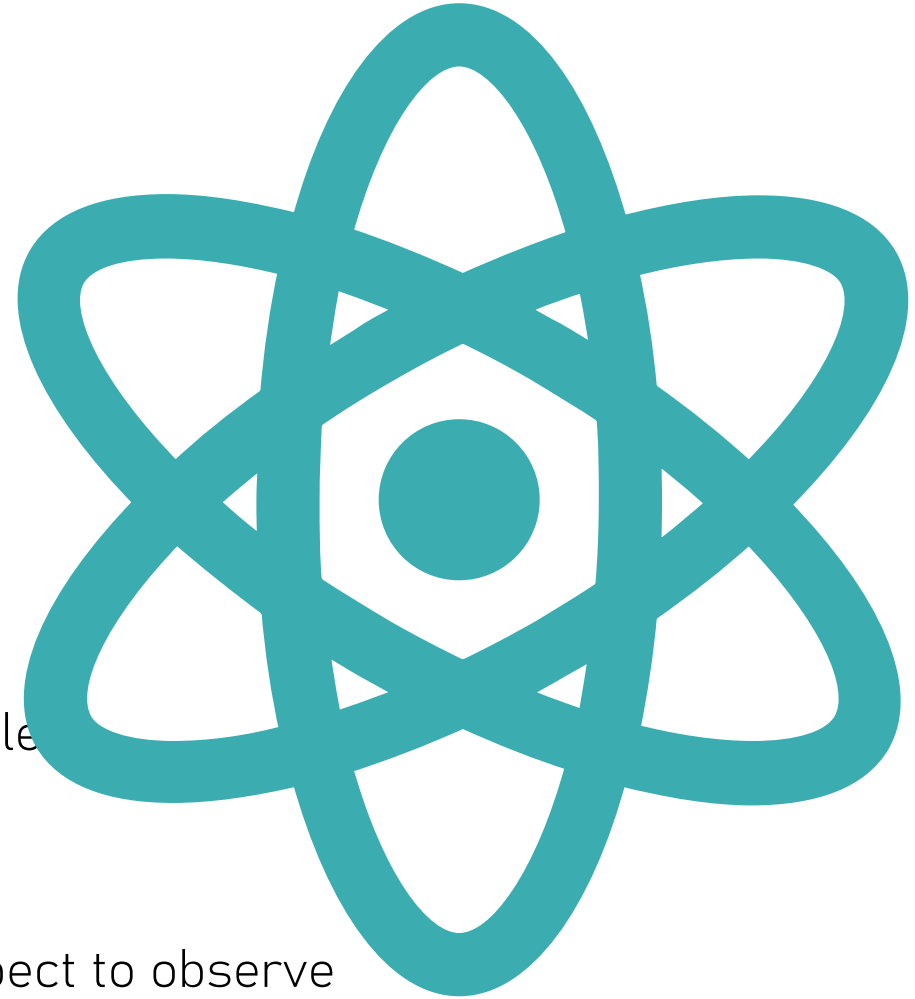
- Quantum mechanics (QM): resistant to a realist understanding
  - What picture of the world does it give us????
- Usual story:
- To make QM compatible with realism, solve the measurement problem (MP)
  - → A variety of realist quantum theories
    - Pilot-wave (dBB), many worlds (MW), GRW, ….
- They are effectively empirically equivalent
  - → Different people make different choices
- Some disagree: no need to solve the measurement problem
    - Information theoretic approach (IT)
- Why is there so much disagreement?
- I argue: no consensus because people have profoundly different motivations, which lead them specific explanatory structures, and then to some theory or another

Axiomatic Quantum Mechanics

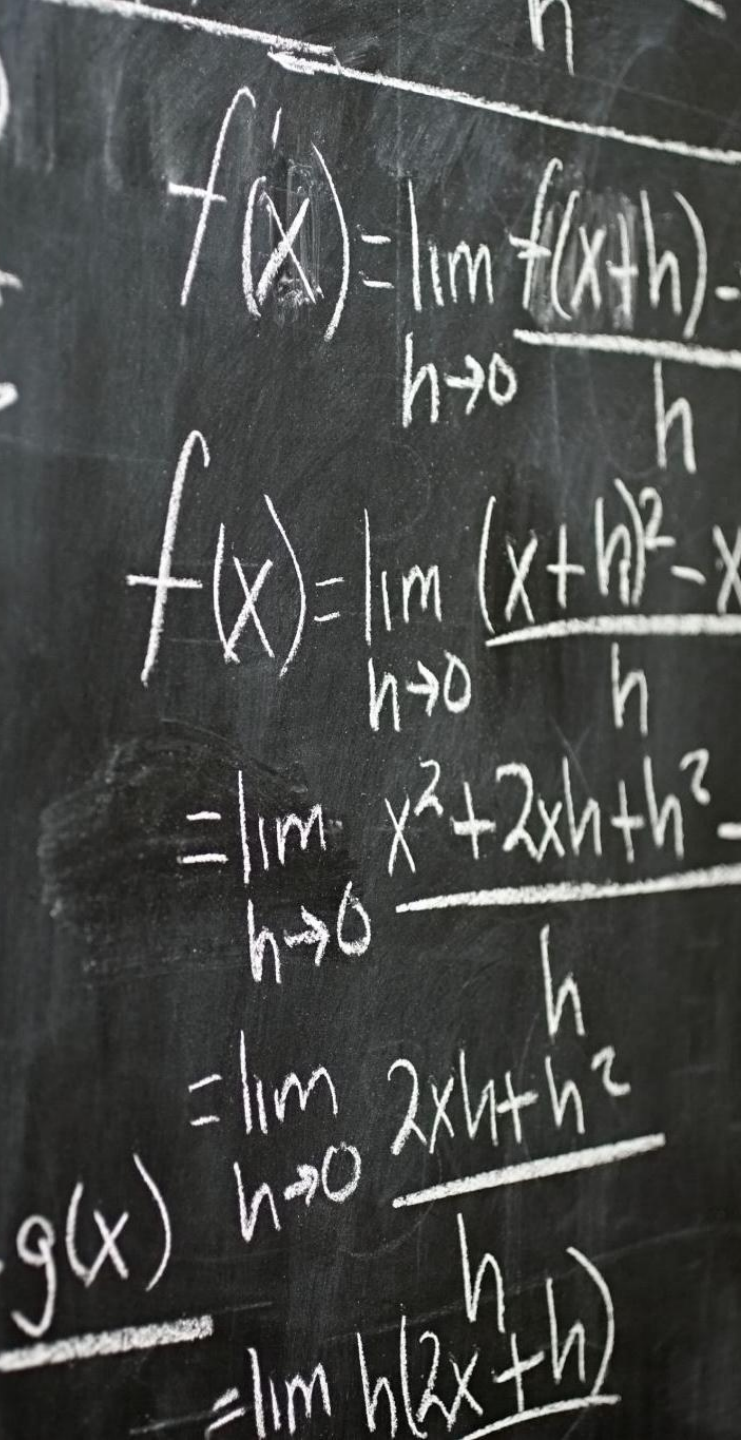
- QM in textbooks ←→ Axiomatic QM
  - presented axiomatically, in terms of postulates
- 1- compete description = quantum state → ray in a Hilbert space
  - When function of position→ wavefunction (wf)
- 2- observables = measurable properties→ self-adjoint operators
  - There is a Hamiltonian (H)=preferred observable, generates the dynamics
- 3- temporal evolution of the quantum state
  - 3a→ Schrödinger equation
    - Linear → superpositions of solutions will be solutions
    - → unobservable macroscopic superpositions → Schrödinger cat
    - → empirically inadequate
  - 3b-von Neumann collapse rule – when "measuring operator A":
    - Eigenvalue-eigenstate rule (EER)
    - → possible values = eigenvalues of A
    - →collapsed the wavefunction= corresponding eigenstate of A
- 4- Born rule = "Prob (some eigenvalue)=|coeff_eigenstate|^2"



AQM vs Classical Mechanics



- Classical mechanics (CM) is very different:
  - Ontology (stipulated and clear) = microscopic point-particles
  - Temporal evolution: = Newton's law
  - Formalism needs no interpretation
- Both AQM and CM: enormous success, albeit of very different type
- CM's explanation: "visualizability" = you can draw pictures
  - Compositionality = everything is composed of micro point-particle
  - Macro properties = in terms of micro dynamics
- AQM: no clear understanding of the micro reality
- AQM's explanation: "expectability" = it tells you what we should expect to observe
- Why this change?
- Standard answer: we cannot do better than this
  - (Among other things) wave-particle duality/complementarity (particle as waves, waves as particles) → a coherent visualizable micro picture is impossible → ignore questions about micro ontology → focus on formalism & expectability→ axiomatic quantum mechanics (AQM)



The Measurement Problem

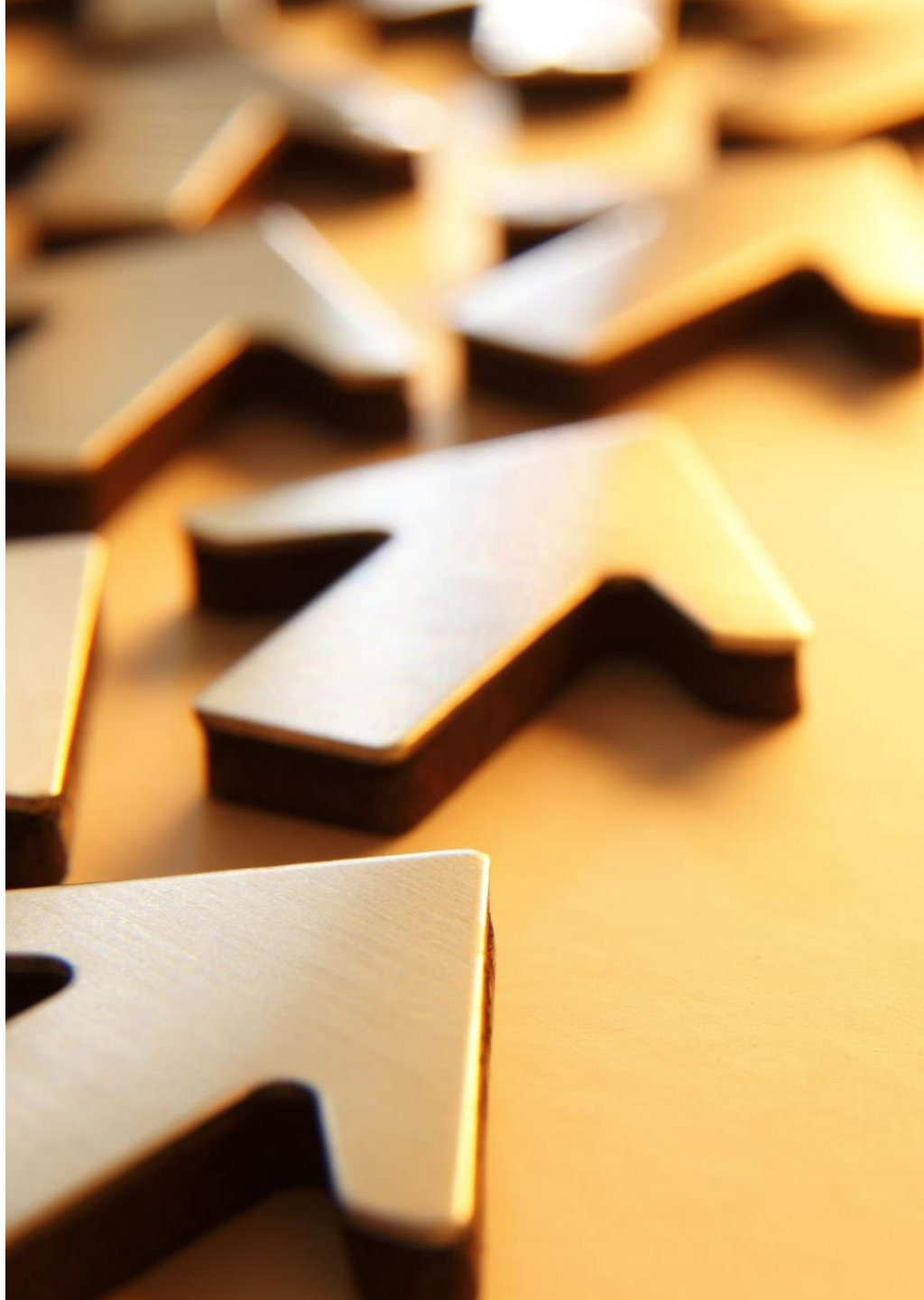
- Perhaps we did not think hard enough?
- What is required from a realist QM?
- Usual answer: solve the measurement problem (MP) (=unobserved macro superpositions) "PRECISELY"
- Collapse rule solves it, but:
  - Two evolution equations → when does the collapse rule apply? What is a measurement? Why is it not another physical process?
- Realist: solve the MP without postulating a measurement-dependent double dynamics
- Usual formulation of the MP (Bell, Maudlin): the following three claims are incompatible
  1. the wf is complete
  2. the wf evolves according to the Schrödinger equation
  3. measurement outcomes are unique

Solutions

- Deny 1: pilot-wave theory (aka de Broglie-Bohm, Bohmian mechanics)
  - Complete description = (particles configuration, wf)
    - Schrödinger evolving wf; particles follow a guidance law
    - Same predictions of AQM
- Deny 2: Spontaneous localization theory (aka Ghirardi-Rimini-Weber, spontaneous collapse/localization, dynamical reduction)
  - Stochastic & nonlinear dynamics for wf
    - Effectively, same predictions of AQM
- Deny 3: Many-worlds theory (aka Everettian mechanics)
  - Schrödinger evolving wf; each superposition term → for all practical purposes (FAPP) isolated 'world'
  - Same predictions of AQM
- Deny nothing: Information-Theoretic approach (IT; neo-Copenhagen)
  - No need to solve the MP to be realist, just use the collapse rule
- Effectively empirically equivalent
  - → Underdetermination by data

Preferences

- Realists disagree about which solution is their favorite
  - Primitive Ontologists (PO)/Local beables:
    - favor dBB (Allori, DGTZ, Esfeld,…; Maudlin; Hubert)
  - Information-Theoretics (IT)/Pragmatists/Relational QM/Qbism:
    - favor AQM (Bub, Pitowsky; Healey; Rovelli; Fuchs)
  - Everettians:
    - favor MW (Wallace, Saunders, Vaidman…)
  - Wavefunction realists (WFR):
    - favor either MW (Ney) or GRW (Albert?)
- Question: why do they disagree?
- My reply: different requirements for a satisfactory realist theory → different type of explanation → different theoretical structure → favoring a given theory



Constructive Explanations, Principle Theories, Interactions and Frameworks

- Einstein's classification about type of theories
  - Constructive vs principle theories
- Flores's refinement:
  - Framework vs interaction theories
- Constructive theories
  - Micro ontology → fundamental building blocks
  - Compositionality and dynamical explanation
    - Macro objects are **compositionally constructed** out of micro objects
    - Micro objects **interact with one another** in a way represented in term of forces/fields/potentials/Hamiltonians/wavefunctions…
    - Macro behavior completely specified in terms of the micro dynamics ('standard reductive explanation'- Gillett)
- → Lego-style
- → Bottom-up

Constructive Explanations, Principle Theories, Interactions and Frameworks

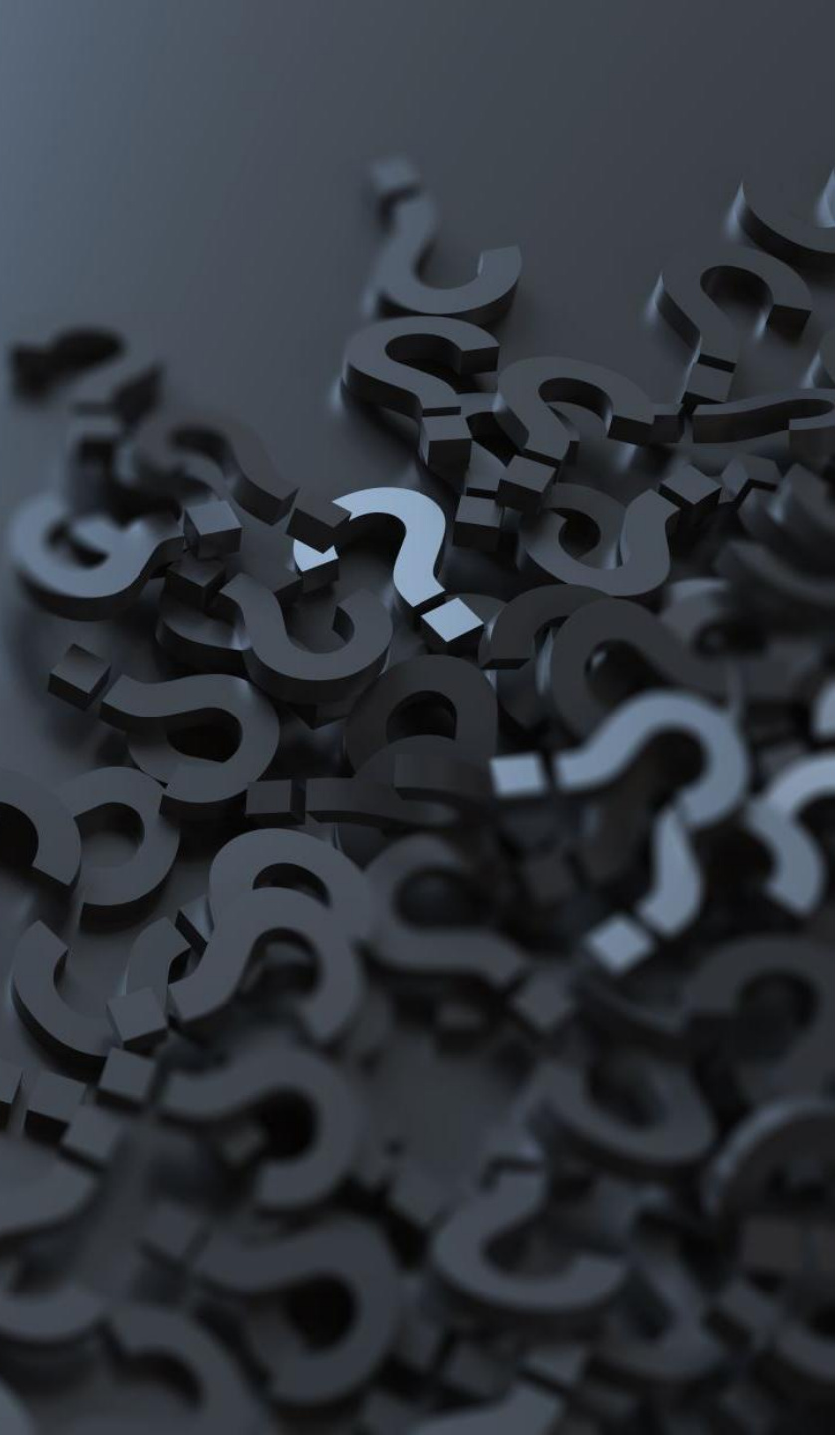
- Principle theories: principles to constrain possible processes
- Aka kinematic theories
  - Because their explanations are not in terms of the dynamics and do not involve interactions
  - → Top-down – Ex: thermodynamics; special relativity w/o Minkowski st
- Framework theories: deal with general constraints
  - no ontology, only formalism; they are physically "empty" until ontology is additionally specified
- Interaction theories: explicitly "fill-in" the framework mentioning ontologies and interactions
- Flores: framework theories are principle theories (they explain because they unify), interaction theories include constructive theories (they provide a mechanistic explanation)

Constructive Explanations, Principle Theories, Interactions and Frameworks

- Einstein:
  - Principle theories are explanatory but also provisional
  - Physics should look for constructive theories
  - Build up macro phenomena from the interaction of micro ontology
- Here:
  - Constructive-principle distinction → useful to contrast PO/IT
  - Interaction-framework distinction → useful to contrast WFR/Everett

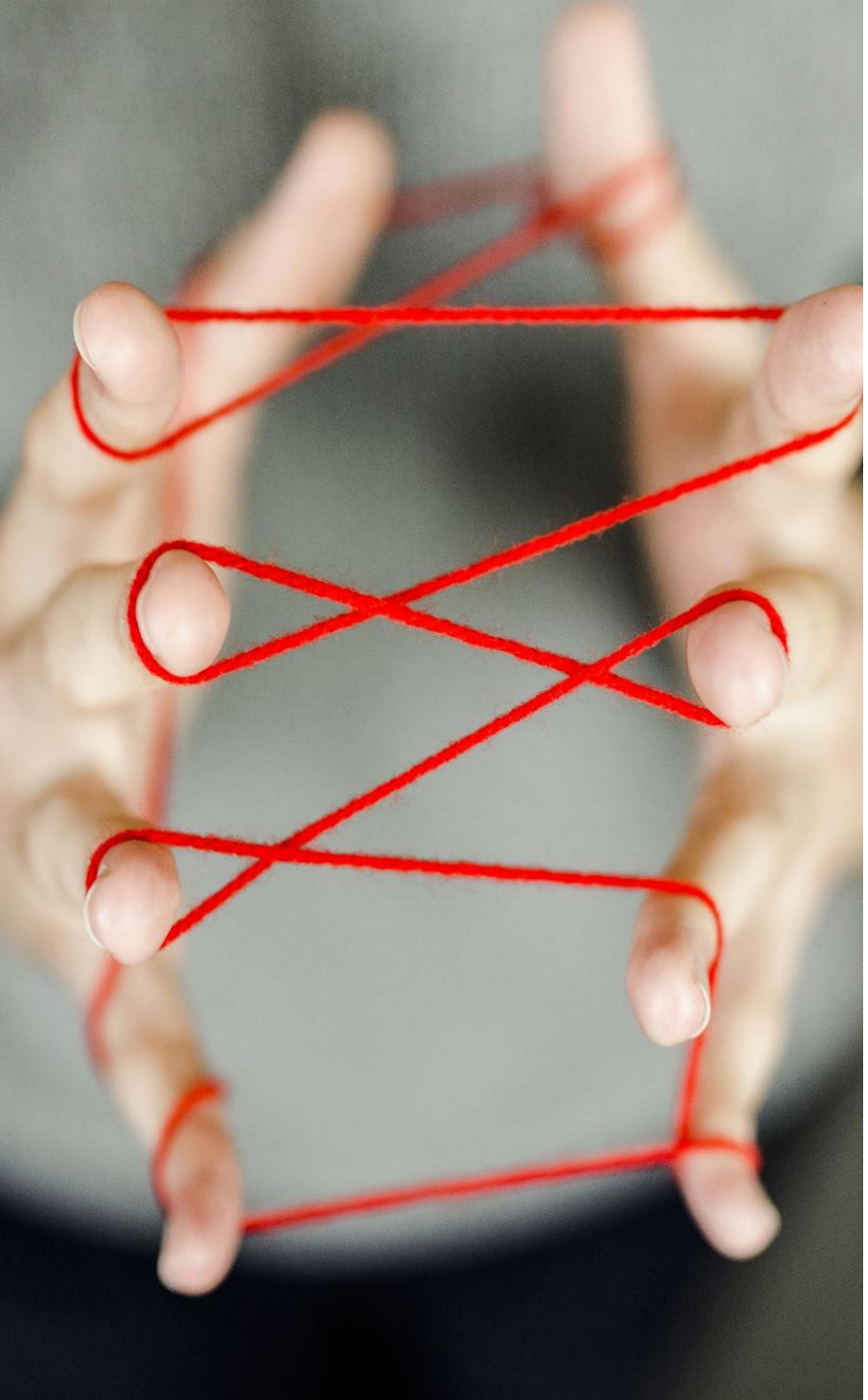
The IT Approach: AQM as a Principle Theory

- IT approach (Bub and Pitowsky)
  - AQM can be seen as a realist theory ←→ solving the MP is not necessary
  - Dogma 1: the fundamental ontology has to be micro
  - Dogma 2: measurements has to be understood in terms of micro processes
- Measurements = primitive and unanalyzable Macro ontology
- AQM is a principle theory: the axioms are the principles
  - Presumably a reason why Einstein disliked AQM
  - Compatible with his idea that AQM was incomplete
  - Compatible with his statistical interpretation of the wf:
    - AQM is in need of a constructive explanation in terms of a still unknown more fundamental constructive theory expressed in terms of 'hidden variables' (micro ontology)



The IT Approach: AQM as a Principle Theory

- Motivation: Empirical Adequacy
  - Schrödinger evolving wf → Macro superpositions→ emp. inadequate
  - Add the collapse rule → empirically adequate → Done! No need to solve the MP
- IT is OK with a double, measurement-dependent dynamics:
  - Because these equations are principles, not dynamical laws
- Explanations as Kinematic Top-Down Systematizations – Principle theory
  - Explanation: what to expect in a given situation, no need for more
  - Top-down: identifying principles to constrain the phenomena, no micro story
    - Hilbert space is to AQM what Minkowski spacetime is to relativity = kinematic set of principles
- Principle theories are to be preferred because independent on the detailed assumption about the constitution of matter

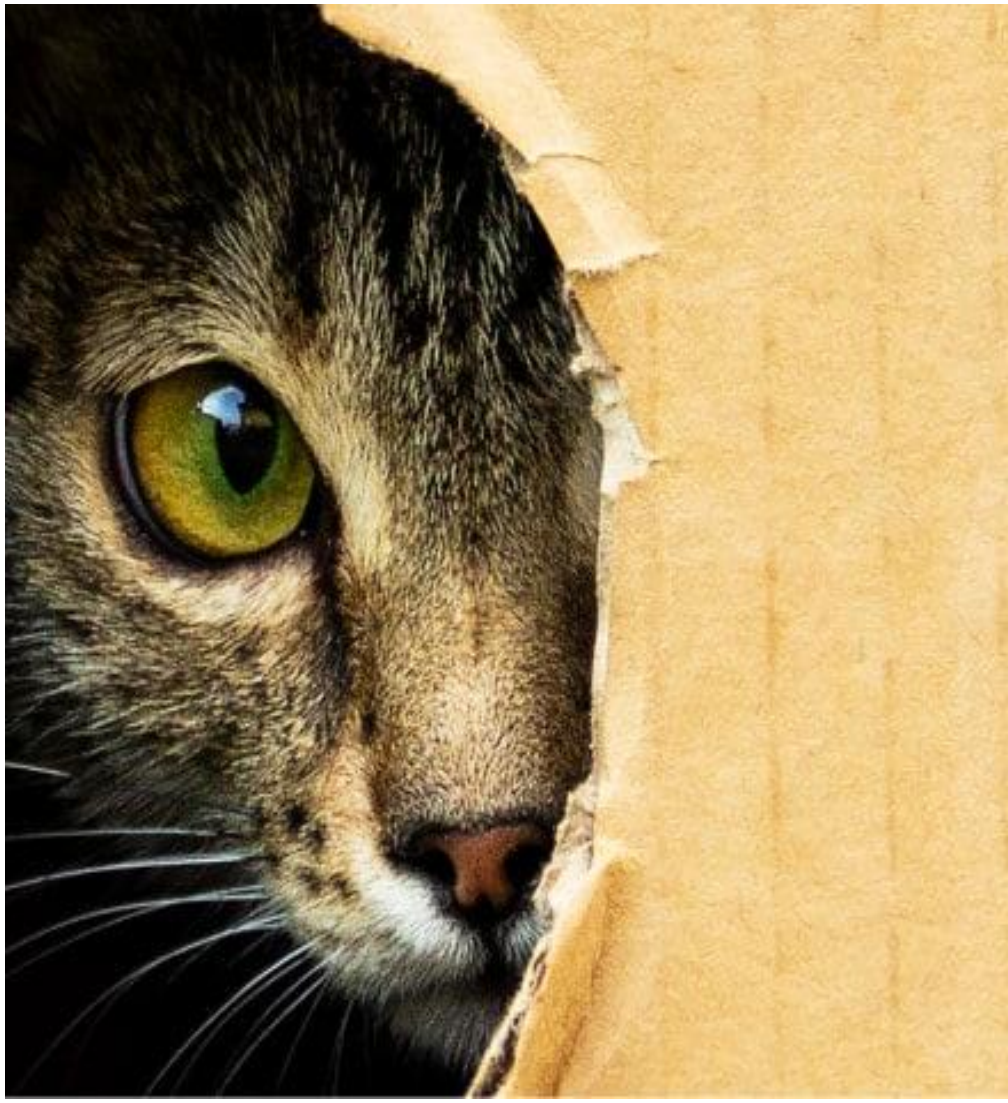


Similar views

- Pragmatist Quantum Realism; Relational QM; Qbism
  - However, Qbists leave open the possibility for a deeper understanding
- These approaches characterize themselves as realist
- How can that be? Realist in what sense?
  - They provide an objective, mind-independent description
- However, from a theory they require very little: only empirical adequacy
  - No micro ontology, no unique dynamics
- Compatible type of realism – Rainforest realism
  - Fundamentally there is only structure
  - Objects = effective descriptions
    - They emerge non-fundamentally as useful patterns
      - 'particles' (chemical compounds, molecules, tables, chairs, and devices) = useful fictions to express certain regularities

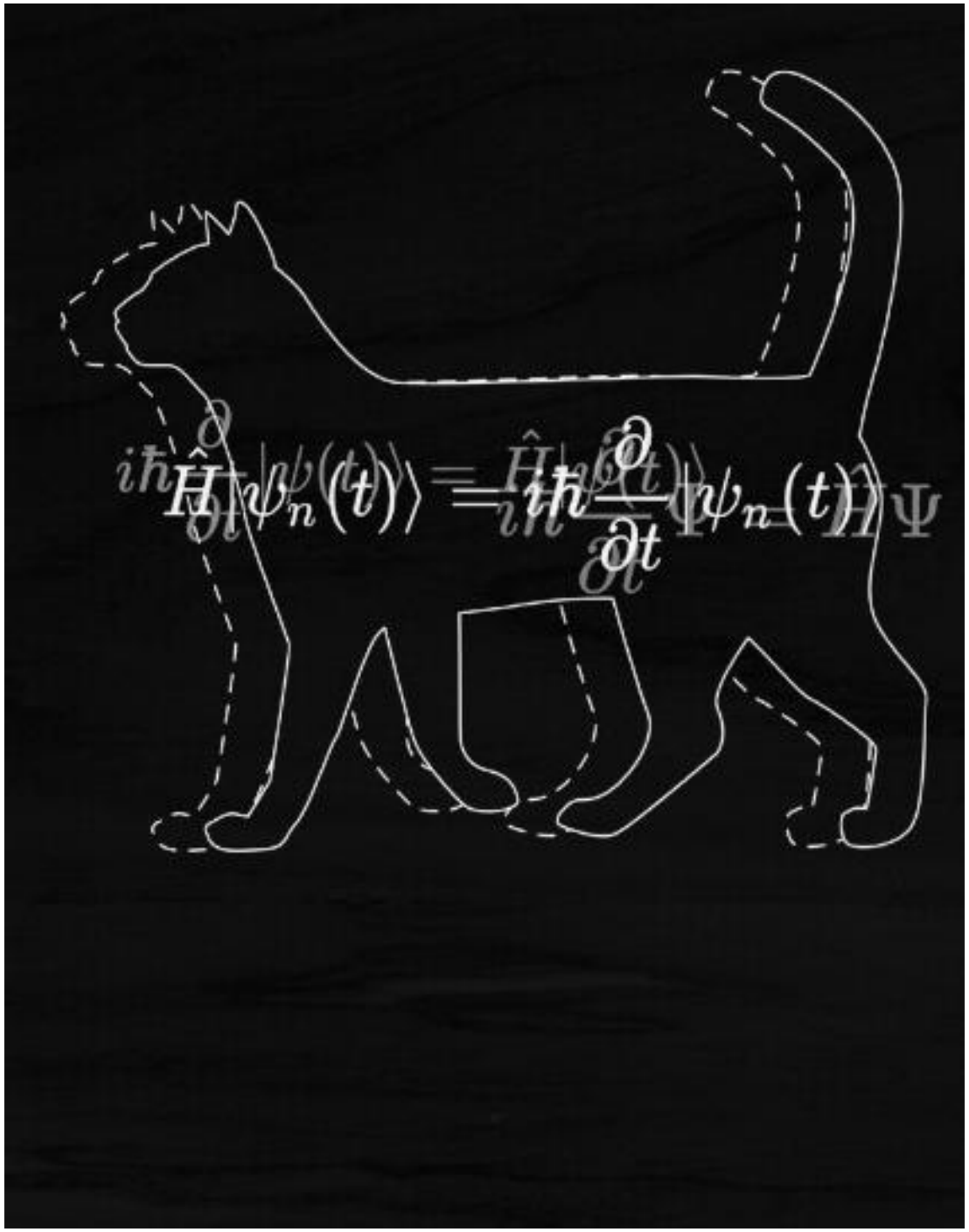
PO: dBB as a Constructive Theory

- PO= spatiotemporal micro ontology (Allori, DGTZ)
- All satisfactory theories need this → solving the MP is not sufficient for realism
  - GRW and MW solve the MP but If they are considered as theories of the wf then they do not have ST ontology → they are not satisfactory
    - You NEED A ST ONTOLOGY TO USE COMPOSITIONAL EXPLANATION
- To be compatible with realism ←→ solve the completeness problem (aka the ontology problem)
  - All realist quantum theories (= which solve the MP) but dBB are incomplete/ need to be completed:
    - GRW→ GRWm,f,p
    - MW→ MWm,f,p



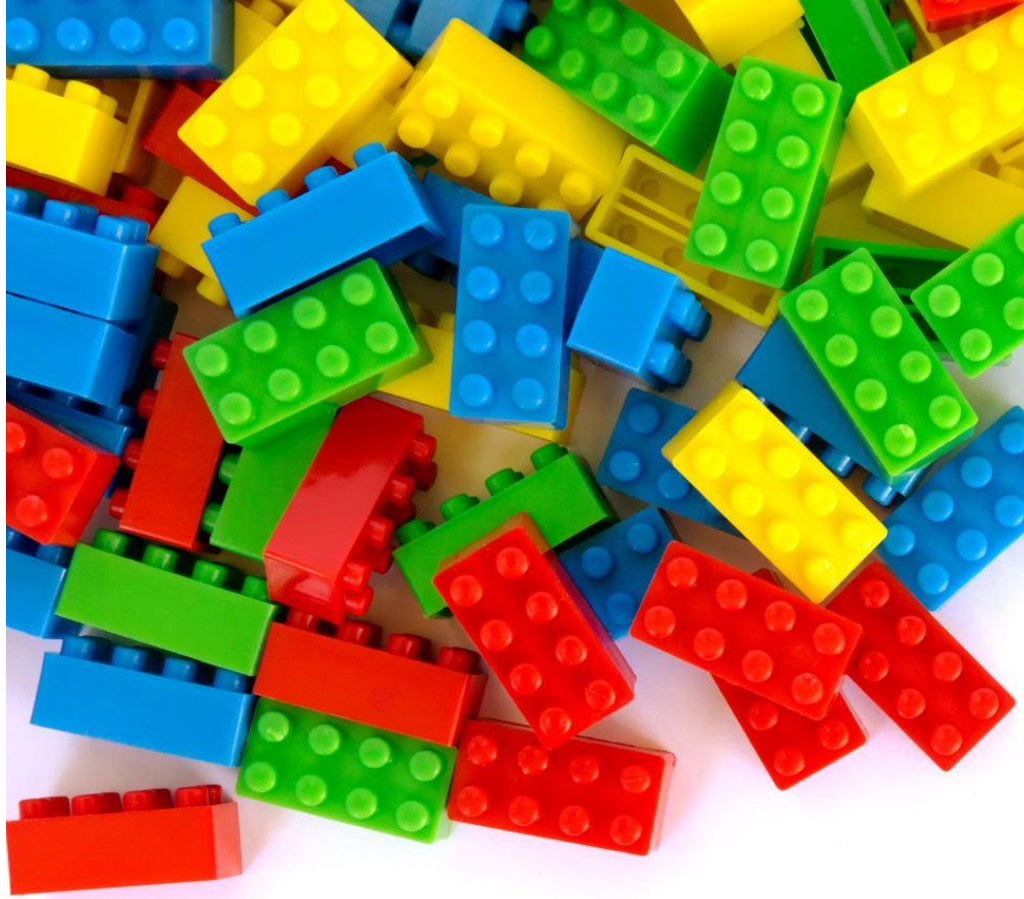
PO: dBB as a Constructive Theory

- Similar approaches:
  - Focus on a spatiotemporal ontology
  - Local beables (Bell, Maudlin, Norsen, Esfeld, Hubert and Romano)
    - Differ in the understanding of the wf
      - A property
      - A primitive entity
      - A local beable
      - A multi-field
      - A law
      - …



P0: dBB as a Constructive Theory

- My motivation: Constructive Explanation
  - Preserve what worked in CM:
    - Compositionality = Macro objects composed by micro objects (the P0)
    - Dynamical reduction = Macro properties and Macro behavior explained in terms micro interactions
- Why constructive theories?
  - Deeper explanation: they explain why a phenomenon happens and why the principles hold

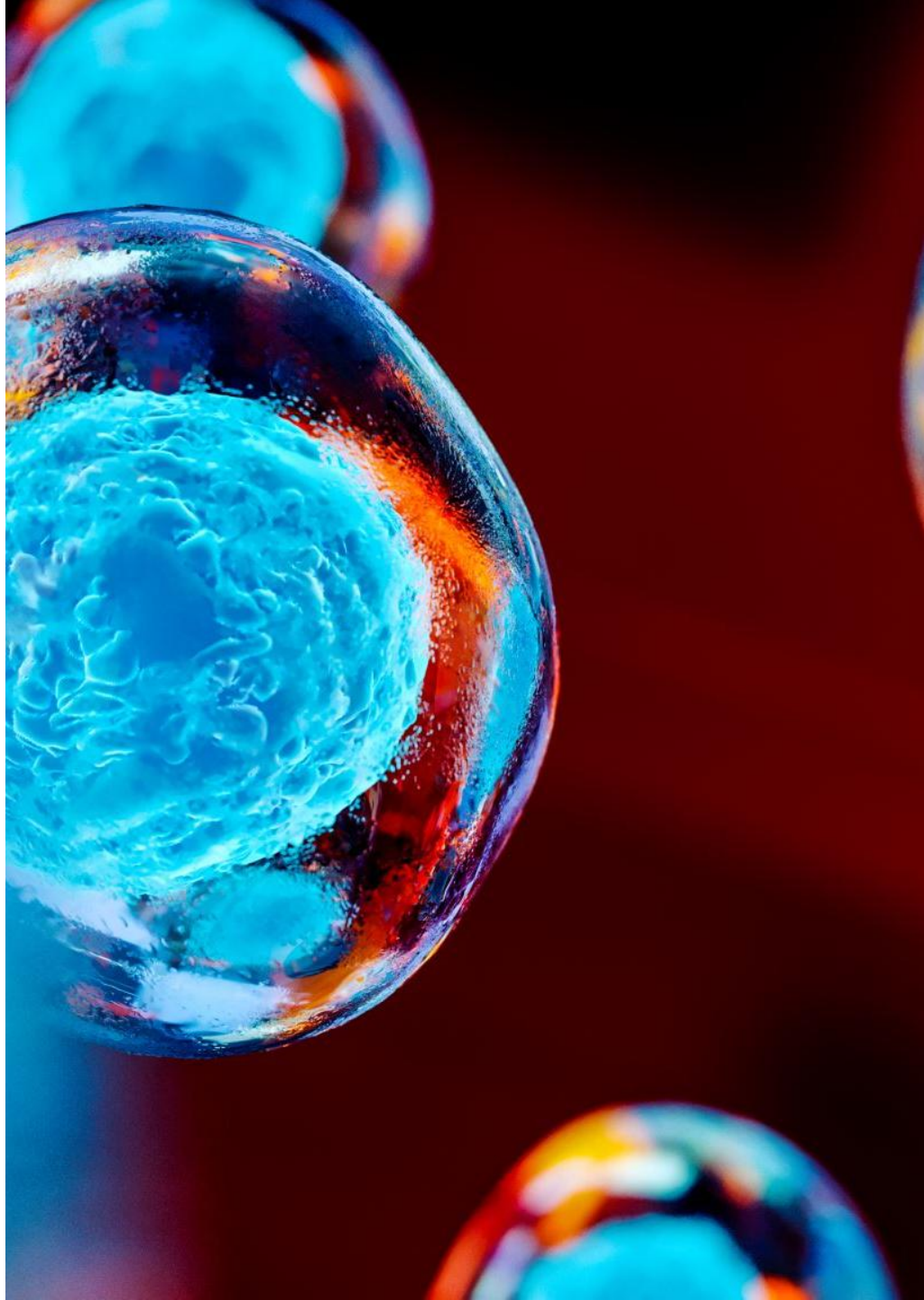


PO: dBB as a Constructive Theory

- What do you need for a constructive explanation ?
  - Bottom-up, Lego brick style
    - Compositionality → micro ontology
    - Dynamical explanation → unique dynamics at all scales
  - Explanans (the PO) and explanandum (the phenomena) in the same space → spacetime
    - Otherwise, you need an unexplained principle
  - Analogy
    - The individual Lego bricks (the PO) which build a castle (the macro phenomena) are in the same space as the castle (spacetime) and they are smaller than the castle (micro)

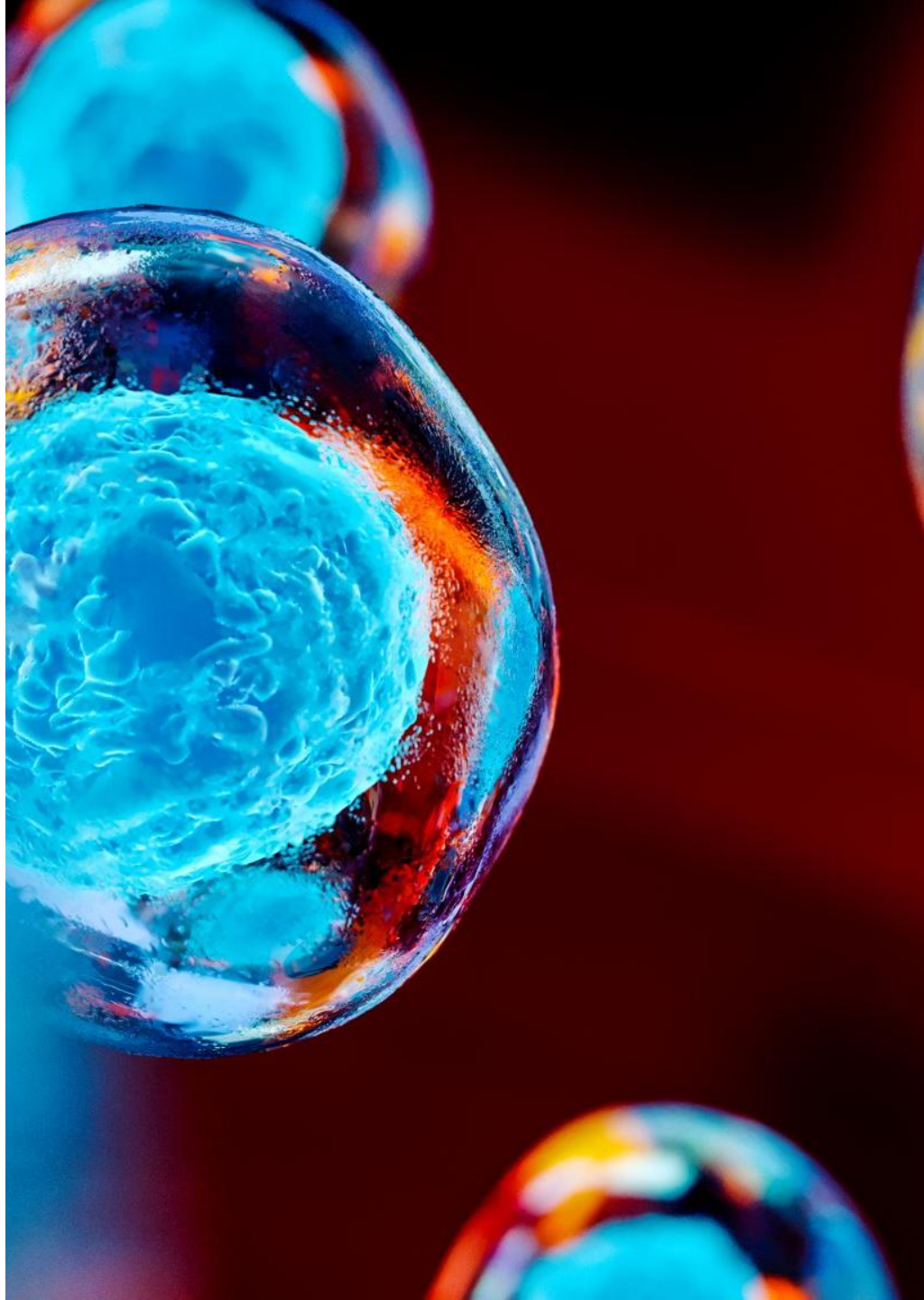
P0: dBB as a Constructive Theory

- History→ physicists have always looked for constructive theories
- Example:
- Pauli explicitly favored constructive theories even if he rejected Lorentz theory of relativity:
- "Should one, [...] completely abandon any attempt to explain the Lorentz contraction atomistically? We think the answer to this question should be No. The contraction of a measuring rod is not an elementary but a very complicated process. It would not take place except for the covariance with respect to the Lorentz group of the basic equations of the electron theory, as well as of those laws, as yet unknown to us, which determine the cohesion of the electron itself. We can only postulate that this is so, knowing that then the theory will be capable of explaining atomistically the behaviour of moving rods and clocks"



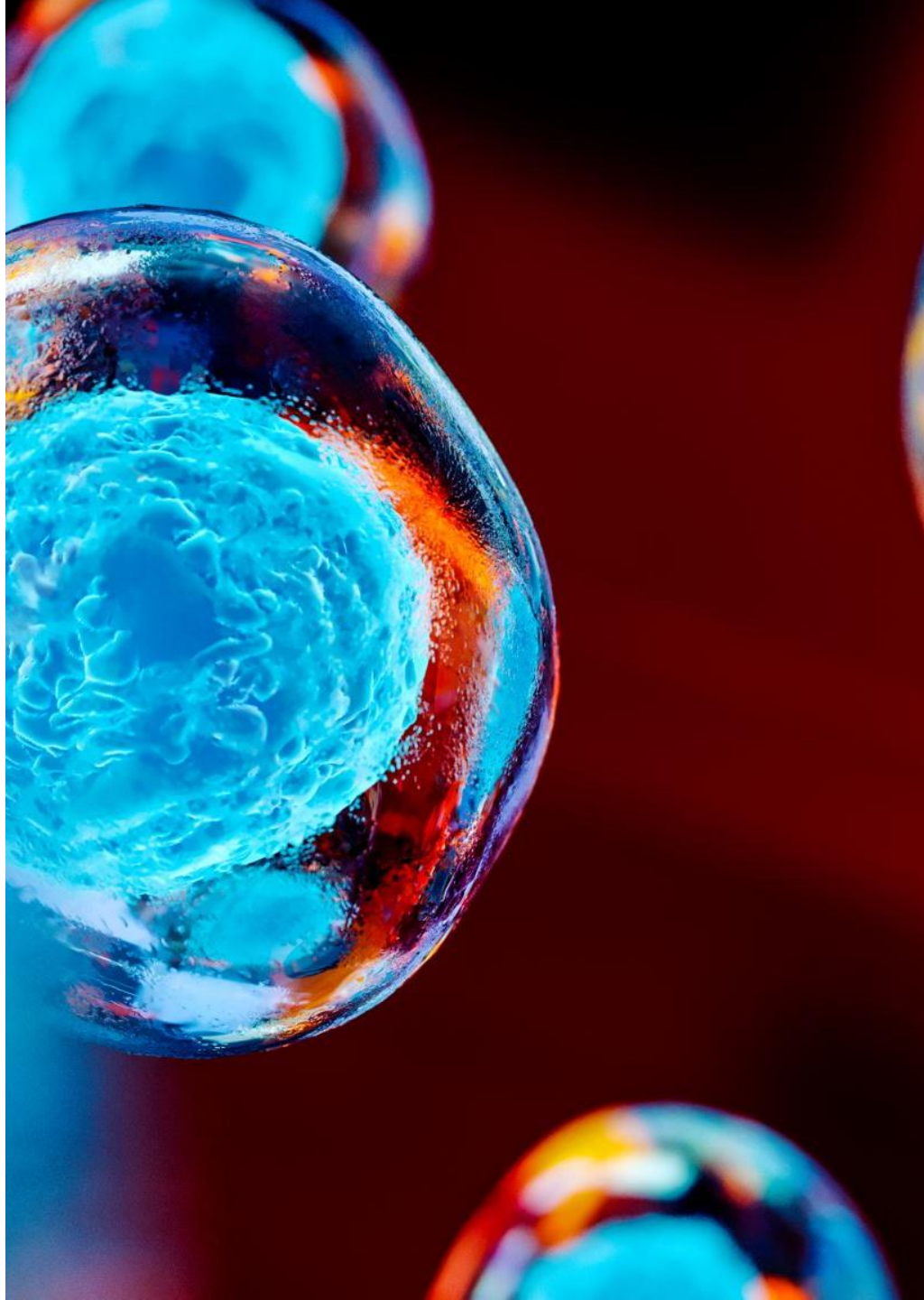
P0: dBB as a Constructive Theory

- Lorentz to Schrödinger indirectly for st ontology (against wf ontology):
  - "If I had to choose now between your wave mechanics and the matrix mechanics, I would give the preference to the former, because of its greater intuitive clarity, so long as one only has to deal with the three coordinates x, y, z. If, however, there are more degrees of freedom, then I cannot interpret the waves and vibrations physically, and I must therefore decide in favor of matrix mechanics"
- Einstein to Lorentz indirectly for st ontology (against wf ontology):
  - Schrödinger's conception of the quantum rules makes a great impression on me; it seems to me to be a bit of reality, however unclear the sense of waves in n-dimensional q-space remains."
- Einstein to Paul Ehrenfest indirectly for st ontology (against wf ontology):
  - "Schrödinger's works are wonderful – but even so one nevertheless hardly comes closer to a real understanding. The field in a many-dimensional coordinate space does not smell like something real"



P0: dBB as a Constructive Theory

- More indirectly for st ontology (against wf ontology):
- Schrödinger:
  - "The direct interpretation of this wave function of six variables in three-dimensional space meets, at any rate initially, with difficulties of an abstract nature"
  - "Of course, this use of the q-space is to be seen only as a mathematical tool, as it is often applied also in the old mechanics; ultimately [...] the process to be described is one in space and time"
- de Broglie:
  - "Physically, there can be no question of a propagation in a configuration space whose existence is purely abstract: the wave picture of our system must include N waves propagating in real space and not a single wave propagating in the configuration space"
- Heisenberg:
  - "Nonsense, [...] space is blue and birds fly through it"



PO: dBB as a Constructive Theory

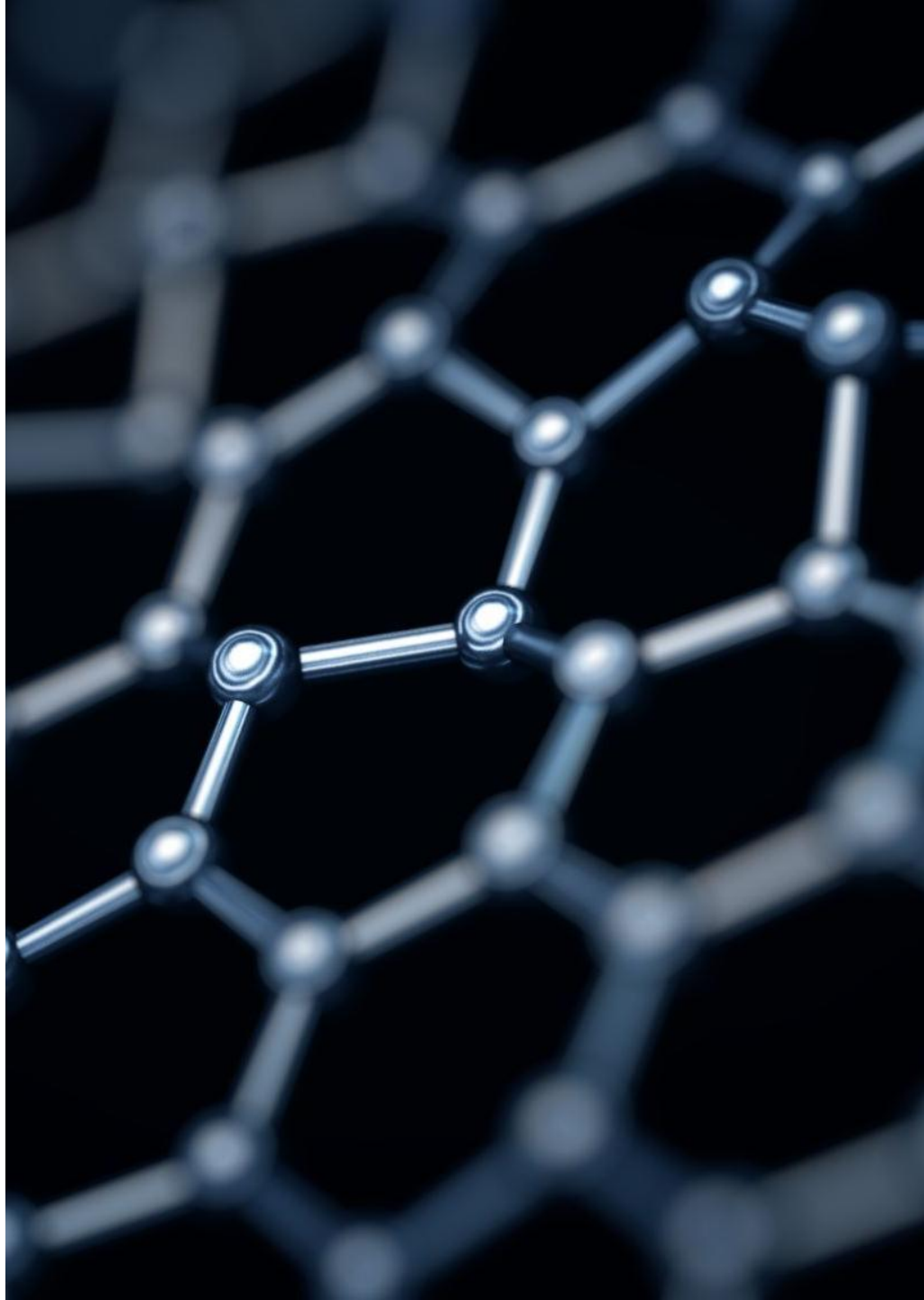
- AQM falls short
  - Two dynamical evolutions; No clear ontology → no constructive explanation
- IT also falls short
  - Two dynamical evolutions; Macro ontology (measurement outcomes) → no constructive explanation
- Both are principle theories:
  - The quantum principles tell us what to expect / constrain the phenomena
    - They are more similar to thermodynamics than to kinetic theory

P0: dBB as a Constructive Theory

- P0:
  - One can (and should!) reduce thermodynamics to CM to get a deeper explanation
    - Absurd to use a gas ontology in the reducing theory
    - New concepts: from gases with P, V, and T, to particles with m, x, v
  - Similarly, one can (and should, especially given that it is possible!) reduce AQM in terms of a deeper, constructive theory
    - Absurd to use the wf ontology in the reducing theory
      - It's worse than a gas ontology since it does not even live in spacetime but in high dimensional 'configuration' space
      - New concepts: from the wf with an amplitude and a phase, to …
        - … Which ontology?

PO: dBB as a Constructive Theory

- … Which ontology?
  - The obvious (simplest): particles in space evolving in time
    - Empirical evidence of tracks in detectors
    - → de Broglie Bohm theory
      - Linear deterministic for wf, deterministic for the ontology
- Otherwise:
  - Waves oscillating in space, evolving in time
    - However: one needs nonlinear dynamics to suppress superpositions (waves superimpose, particles do not)
    - → GRWm (also stochastic for the wf, and the PO)
    - → de Broglie double solution (deterministic)
      - PO= 3d wave guided by the dBB guidance law
      - Nonlinear evolving wf in configuration space which has "only a statistical and subjective meaning"
      - However: superluminal signaling (controversial); still a work in progress



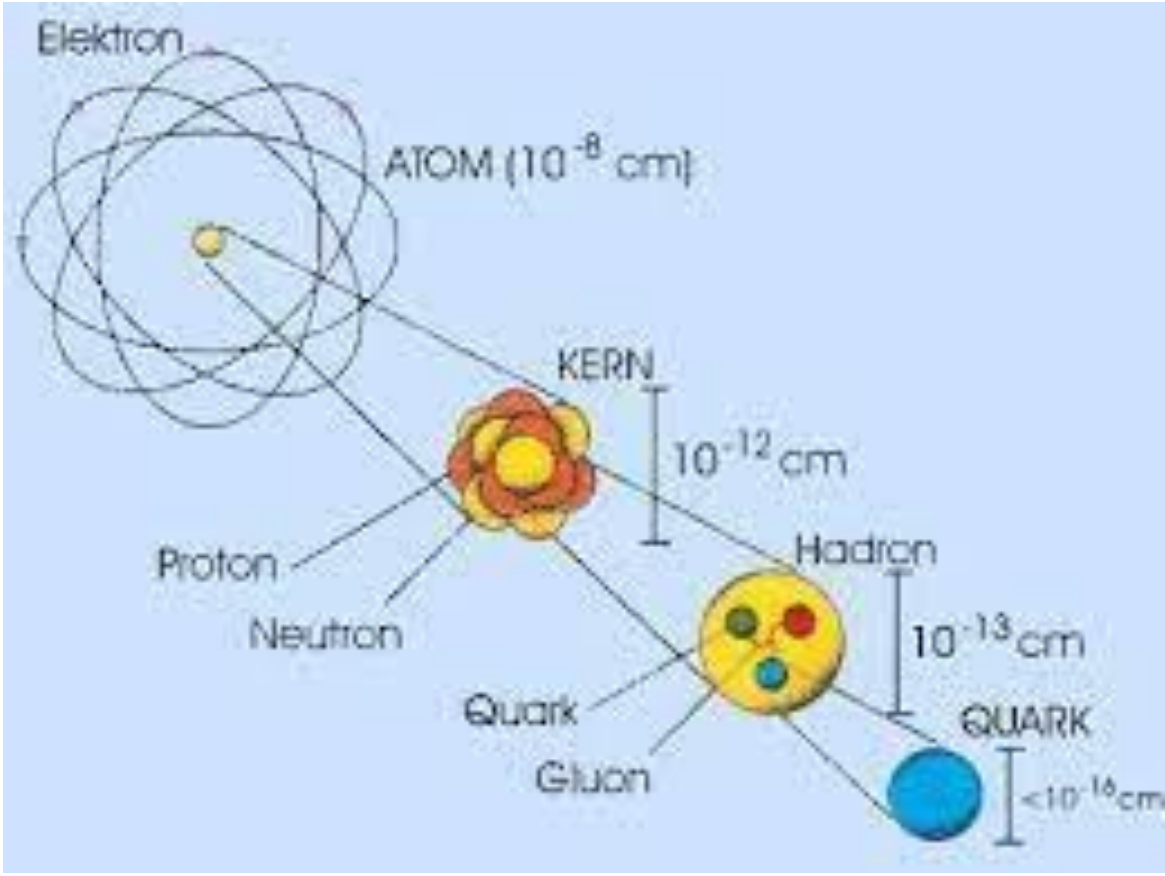
PO: dBB as a Constructive Theory

- More exotic ontologies are possible
  - Spatiotemporal events ("flashes")
    - Linear deterministic wf evolution; stochastic for the ontology → Sf
      - However, many-worlds character
    - Nonlinear stochastic wf evolution, stochastic for the ontology → GRWf

      - But why would we want these?
      - dBB is already the simplest, most straightforward constructive quantum theory
        - OOMOW=Obvious Ontology Moving the Obvious Way (Goldstein)

PO: dBB as a Constructive Theory – if there's time

- Explanations as Dynamical Bottom-Up Constructions
- Specify a ST fundam ontology and its dynamics → everything else follows compositionality and dynamically
- Micro entities aggregate into composites:
  - Electrons, quarks and gluons→ protons, neutrons → atoms→ molecules → gases, solids, liquids…proteins, crystalline structures, viruses, bacteria, animals, stars, and nebulas
- Non-fundamental entities = non-fundamental ontology of high-level sciences
- Remarkably, they are autonomous: they behave as if they are effectively fundamental/not composite
  - Chemistry explains the behavior of elements without invoking their inner composition
  - Arguably, this is what allows us to discover any law at all
  - PO= identifying the micro compositions of these non-fundamental entities can explain why these theories are successful



P0: dBB as a Constructive Theory if there's time

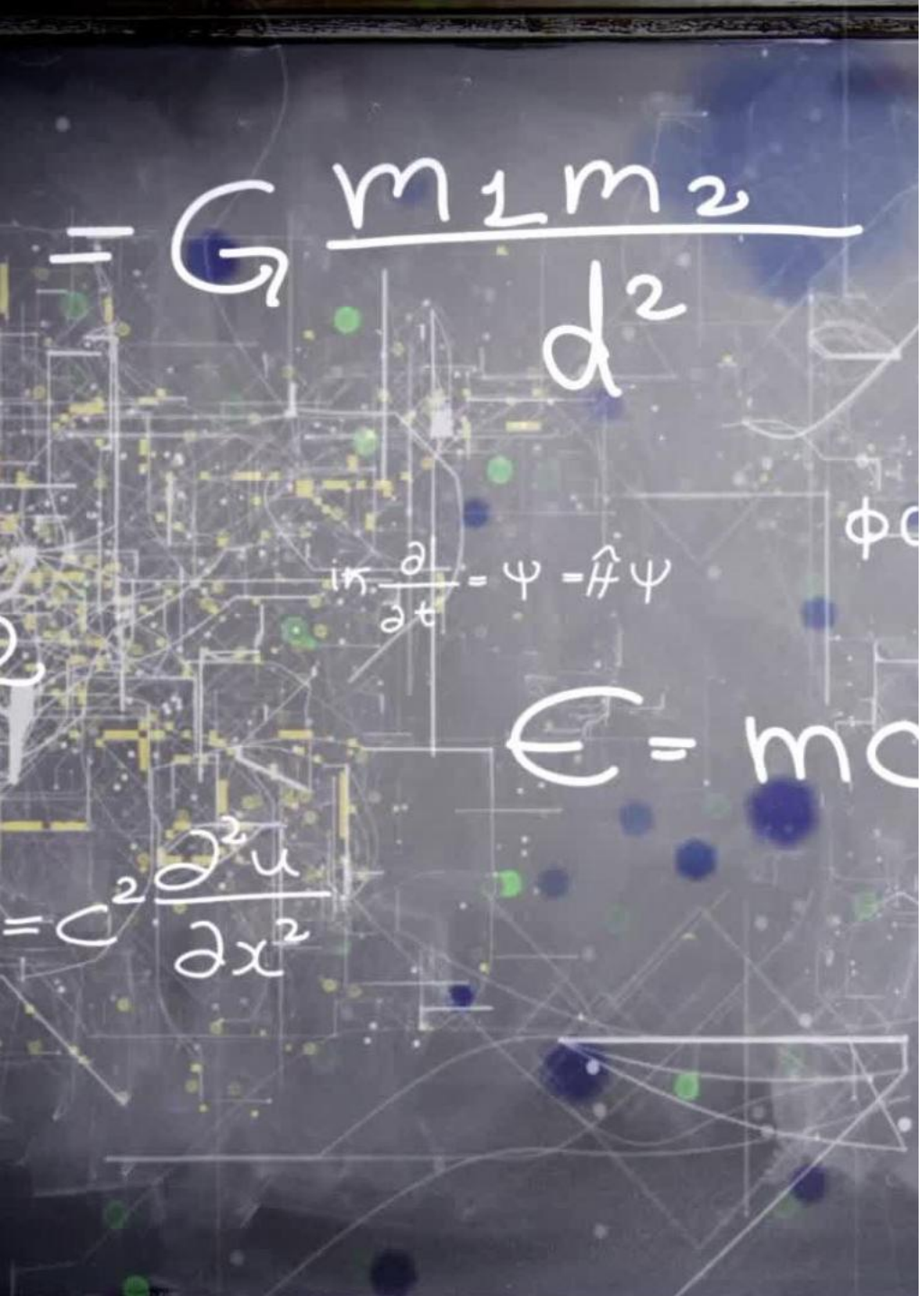
- Fundamental ontology = precise
- Non-fundamental effective ontology = may be vague
  - Ex of Precise (micro/meso level): water = 2 atoms of H, 1 atom of O
    - Reason: Micro explanation = constructive (compositionality and dynamics) → precise ontology
      - an electron turning right in a magnetic field → explanation: negative charges turn right for that direction of the magnetic field
  - Ex of Vague (Macro): tigers (no precise number of cells)
    - Functionally defined : a tiger is as a tiger does
    - Reason: Macro explanation = teleological (desires and intentions) → vague
      - a tiger hunting a deer → explanation: she is a carnivore and that she needs to eat every XYZ hours
- Be that as it may:
  - Effective ontologies of high-level sciences can be reduced, compositionally and dynamically, to the fundamental micro ontology.
  - Compatible with high-level sciences being explanatory in virtue of using their Macro ontology/Macro language

Everettians: Unitary QM as a Framework

- Usually, IT → 'not realist enough'; Wrong to have 2 evolution equations; Wrong to think of measurements as primitive; Not simple or elegant enough
- Everettians (Wallace & Oxford group,Vaidman) = pure wf dynamics
- Motivation: Practice in Physics
  - Physicists never use the collapse rule (no IT), never use 'hidden variables' (no dBB), never use a modified Schrödinger dynamics (no GRW)
  - Rather, they use the Schrödinger (unitary) dynamics, operators as observables, and the Born rule
- How to make realist sense of these practices?
  - Best explanation: Many Worlds!
  - Superpositions describe multiplicity of approximately classical, non-interacting emergent classical "worlds"
  - Decoherence (the interactions with the environment)
    - Solves the "preferred basis" problem (why the wf of all bases?)
    - Makes the worlds effectively non-interacting (suppression of interference)
  - Rationality constraints → to weight the worlds by the Born probabilities

Everettians: Unitary QM as a Framework

- Wallace: CM is not a constructive theory, CM is not even a single theory
- Usually, CM= point-particles CM but there are other CMs:
  - The dynamics of a spring, the vibrations of a rigid body, the flow of a fluid, the behavior of fields.
  - They are all CM because of their common formalism:
    - In a phase space with a common mathematical structure
    - Systems= represented by elements of phase space
    - Hamiltonian generates the dynamics
    - Systems are separable = state of composite is the sum of their components
  - → CM is a framework



Everettians: Unitary QM as a Framework

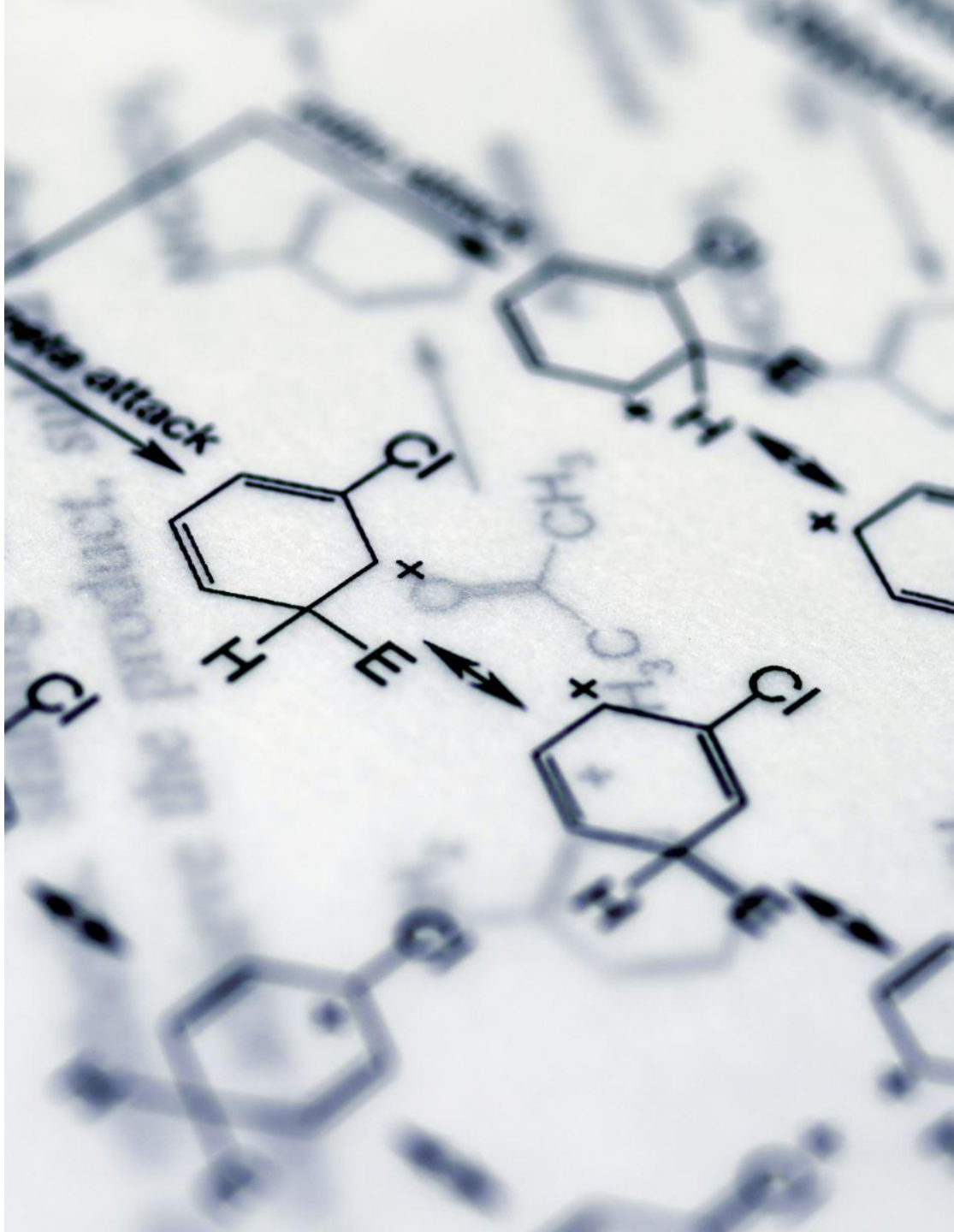
- Unitary QM is also a framework:
  - In a phase space, Hilbert space
  - Systems= represented by elements of phase space
  - Hamiltonian generates the dynamics
  - Systems are NO LONGER separable (bc of entanglement)
- MW= the only theory which describes the whole framework, not specific theories
- Consequently, misguided to ask for an ontology because it depends on the specific theory
- However, relativity as a theory about spacetime → spatiotemporal ontology (like PO)
- Wallace and Timpson = spacetime state realism
  - density matrices values in spacetime regions
- Vaidman: matter density field in spacetime (p.c.)
  - "Reality is only wavefunction" = "Reality is wave-like, and such a wave is entangled" (thus it does not live in 3d space)

Everettians: Unitary QM as a Framework

- Explanations as Dynamically Emerging Structures
- Embrace superpositions → NO Macro ontology (unlike IT)
- Relativity → spatiotemporal ontology (like PO)
- Framework constrains the phenomena & structuralist techniques
  - Born rule= principle of rationality (like IT)
  - Worlds = Structures dynamically emerge (decoherence)→ dynamics is important (like PO)
  - Macro objects = functionally emerge as useful patterns → NO micro ontology (like IT, unlike PO)
  - Worlds and micro objects = explanatorily useful structures ← → expressed in the vague Macro language (like PO)
  - Top-down approach: from the quantum state read off the non-fundamental structure (worlds, objects, tigers, DNAs, etc.). (unlike the PO= Bottom-up constructive understanding)

Everettians: Unitary QM as a Framework

- Everettians: Spatiotemporal ontology + structural explanation (instead of compositional)
- Independent → Rainforest realism or Wavefunction realism = structural explanation without a spatiotemporal ontology
- Why not compositional explanation?
  - Because they have a wave-like ontology
    - A particle ontology would deviate from practice too much (really?)
      - See later
  - A wave-like ontology → spreading → vagueness → structuralist techniques



WF Realism: QTs as Interaction Theories

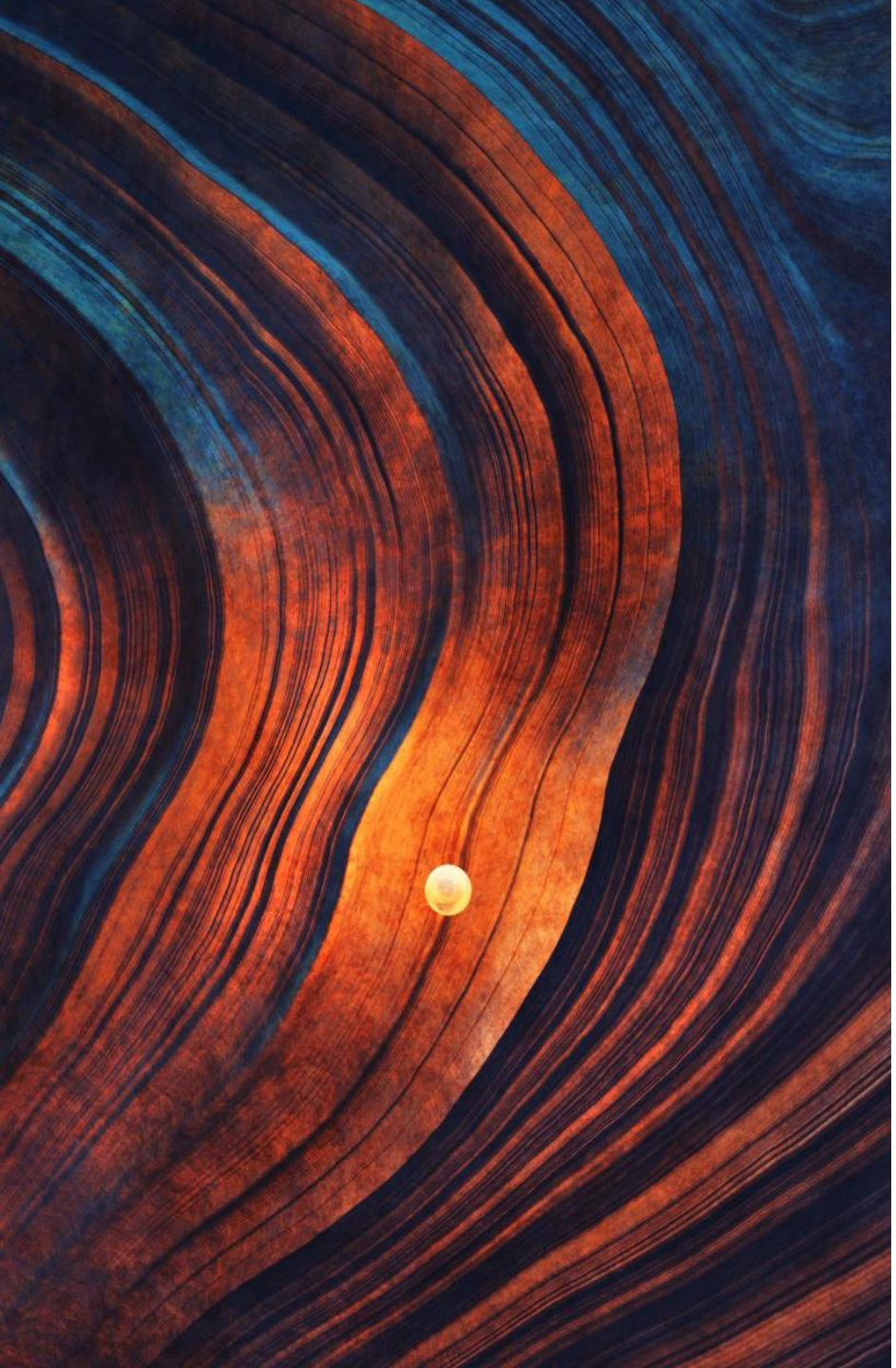
- WF Realism = the wf as a field in high-dim 'configuration' space is the ontology of all solutions of the MP (Albert & Loewer, Ney)
- Motivation 1 : Simplest understanding of these theories (Albert)
  - MW, GRW: Their main equation is about the behavior of the wf → wf is the otology
  - dBB:: 'marvelous' particle & wf in config space (Albert)
- Motivation 2: Best way to understand entanglement (North, Lewis)
- Motivation 3: Only local and separable ontology in the fundamental space (Ney)

WF Realism: QTs as Interaction Theories

- Locality (aka local causality)= interactions propagate continuously at finite velocity
- Always an assumption in physics before QM
  - To describe systems as isolated; to identify causes and effects
  - Theory of gravitation: nonlocal, but
    - Quickly decreases with the relative distance → FAPP, we can neglect the effect of distant objects
  - Relativity → new limit: c is the maximum velocity
  - AQM: collapse is nonlocal
  - Violation of Bell's inequality → all quantum theories are nonlocal
- Nonlocality is built in the wf, since it is a function of all the particles
- If the fundamental ontology is not in spacetime but in configuration space the metaphysics is local in that space

WF Realism: QTs as Interaction Theories

- Locality = a property of the interaction
- Separability= a property of matter
- In configuration space the wf is separable (completely determined by its phase and amplitude)
- Why is separability worth keeping?
  - (To retain compositionality. However, WFR's explanation is not compositional)
  - Separability is consistent with Humean supervenience, which is simple
- Wf Realists:
  - In spacetime locality and separability are lost
  - Allow non-spatiotemporal ontology because in high-dimensional configuration space one can keep them both
    - PO, IT= separable but nonlocal (they have a spatiotemporal ontology)
    - Everettians= local but not separable (in each branch the interaction is local but the object across branches is nonseparable)
- Which theory?
  - either GRW or MW as theories of the wf in configuration space; not dBB

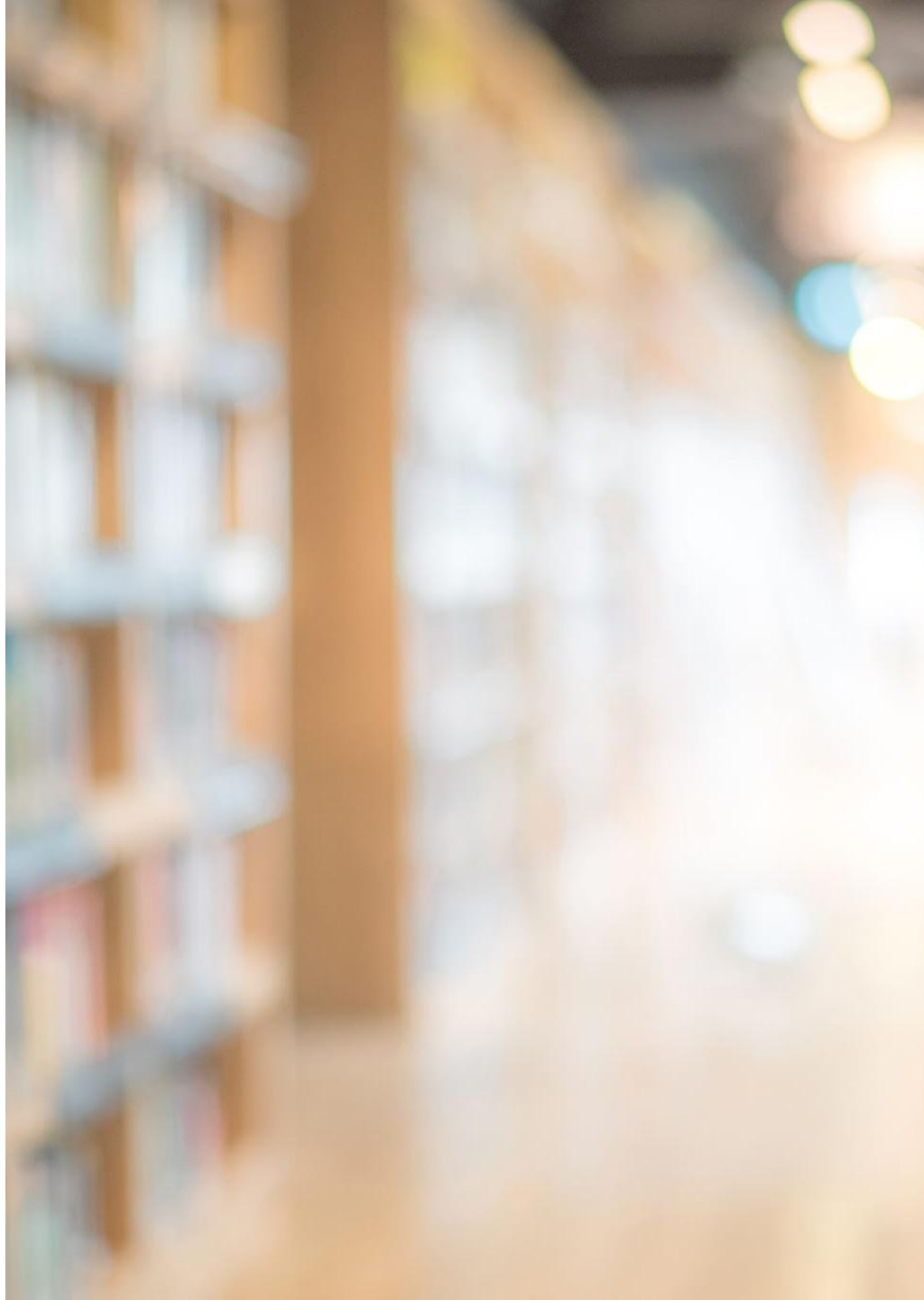


WF Realism: QTs as Interaction Theories

- Explanations as Non-Constructive Dynamical Hybrids
- Fundamental physical space = configuration space
- Spacetime and objects in it = non-fundamentally emerge
- Emergence through principles which explain
  - Why we should expect to observe a 3d world
    - Albert: the number of dimensions displayed in the Hamiltonian (3) are privileged
    - Ney: the number of dimensions respecting fundamental dynamical symmetries (3) are privileged
    - Carroll's vector space realism (aka Hilbert space fundamentalism): the dimensions allowing the simplest decomposition of Hilbert space into subsystems (3) are privileged.
  - Why we should expect at some level micro 3d objects
    - Albert and Loewer: modify the EEL to redefine 3d particles in terms of their location
    - Albert: 3d micro particles are 'functional shadows' of the high-d wf
    - Ney: micro 3d particles as derivative 'bumps' of the wf
- Compositionality to explain 3d Macro objects
  - Compositionality in step 3→ WFR care more about micro than Everettians
  - WFR use the dynamics in step3; Everettians use it to extract the non-fundamental Macro ontology from the fundamental spatiotemporal one

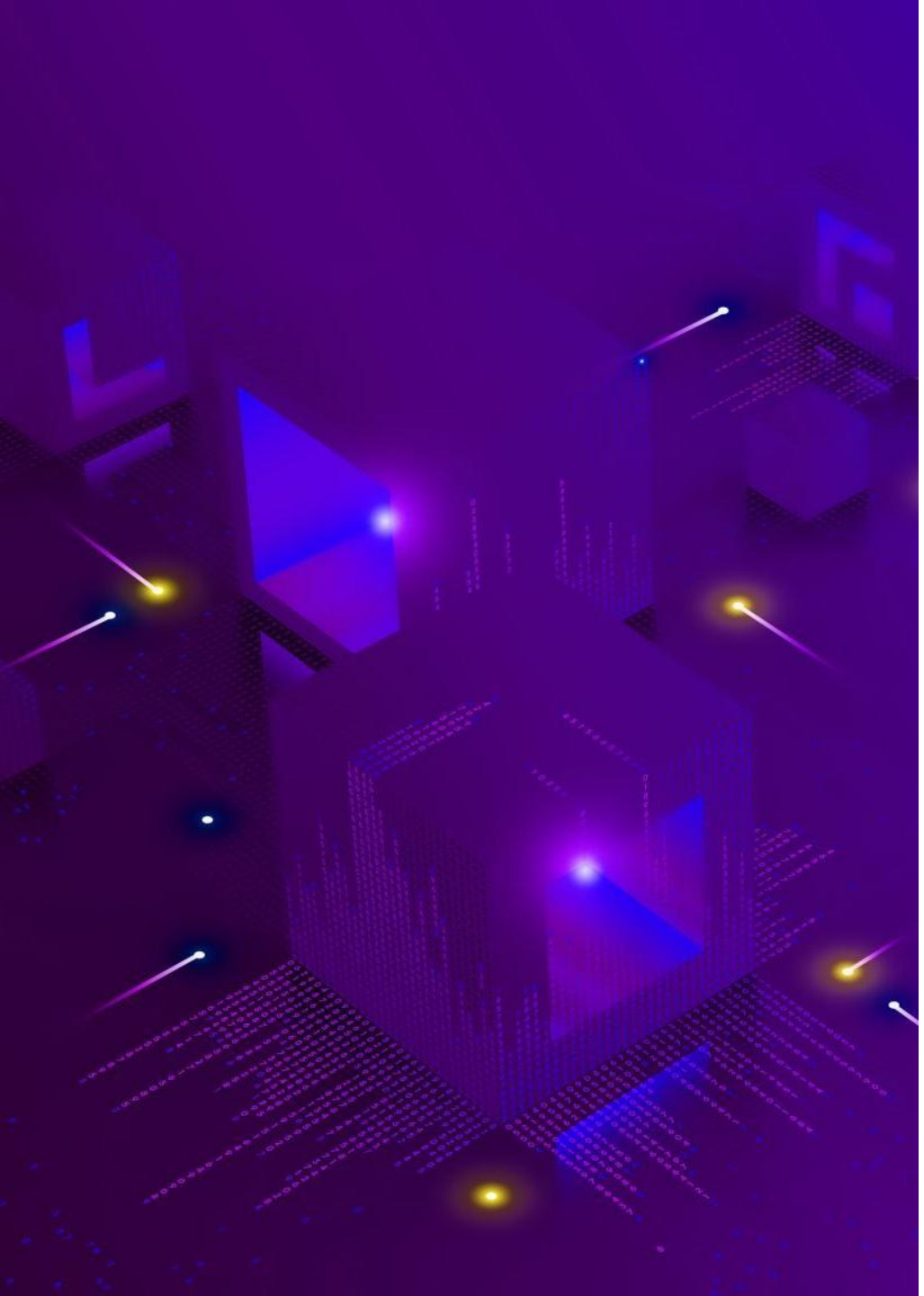
WF Realism: QTs as Interaction Theories

- Relations with other views?
  - PO/IT ← → Principle/constructive theories
  - Everettians/WF Realism ← → framework/interaction theories
- Principle theories → constrain the phenomena, which are physical processes
- Frameworks → devoid of direct physical significance ←→ empty mathematical structures which could be interpreted freely
  - Like argument forms which are neither T nor F
  - Many different ontologies compatible with the same framework
- Interaction theories ← →when you 'instantiate' a framework
  - CM: dynamics of point-particles in 3d
  - Not necessary in 3d thought → not necessarily constructive
  - WFR: QTs are about the dynamics of some fundamental ontology (the wf in conf space)



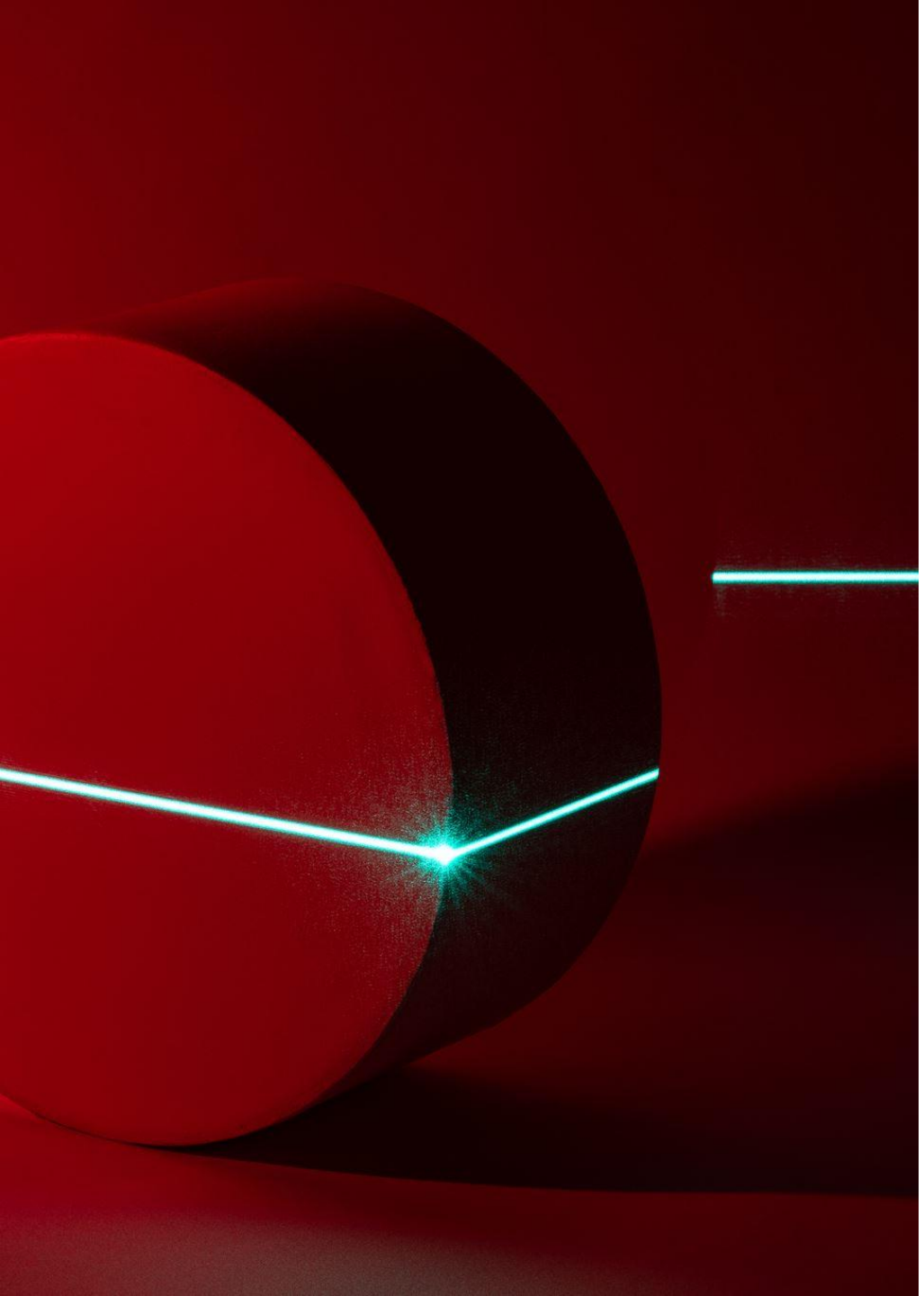
The Disagreement in a Table

View	Motivation	Fund Ontology	Explanation	Theory
IT/ QBism / Pragmatists	Empirical adequacy	Macro ontology	Principle explanation: principles constrain the phenomena.	AQM
Primitive Ontology/Local Beables	Compositionality and dynamical reduction	Spatiotemporal & micro ontology	Constructive explanation: 1-Compositionality (Macro objects composed of micro fundamentals) 2-Dynamical reduction (macro behavior in terms of the micro dynamics)	dBB
Everettians/ Spacetime State Realism	Coherence with physical practice	Spatiotemporal ontology (if needed)	Structuralist/functionalist/dynamical explanation: 1-Macro phenomena = dynamically emergent useful structures 2-Objects are as what they do	MW
Wavefunction Realism	Preserve locality and separability	Local & separable (not necessarily in spacetime)	Non-constructive/ dynamical explanation: 1-principles to recover non-fund 3d micro ontology from the wf 2-Compositionality to get Macro objects	MW, GRW_0



Summary and Conclusion

- My thesis:
  - No consensus about which theory is the best realist QM because no consensus about which type of explanation is to be preferred
    - Principle explanation → IT→ AQM
    - Constructive explanation → PO→ dBB
    - Frameworks → Everettians→ MW
    - Interactions → WF Realism → MW, GRW_0
  - (Personally: constructive explanation is the best motivated)



Some open questions

- 1- how can WFR justify the importance they give to locality and separability in high-d?
  - locality and separability are desiderata for a spacetime ontology, not for a high-d one
  - They appeal to Humean supervenience (HS) but that seems a weak reason
    - Anti Humeans will not be convinced
    - Even Humeans might find preserving constructive explanation more compelling than preserving HS

Some open questions

- 2- Why Everettians insist on a wave ontology, knowing that this inevitably leads to a MW picture?
- They want a spatiotemporal ontology because of relativity
- A particle ontology is ST, and also it would get rid of the multiplicity (=radical metaphysics)
- Possible reply: radical departure from physical practice
  - However, this does not seem true:
    - Physicists talk about particles all the time
    - Even if they did not, why should we care about their practice?
      - Because it is incredibly successful, and success is evidence of truth
      - Nonetheless, QM was developed by instrumentalists; why should we follow their practices? Esp, if they lead to revisionary, empirically unsupported metaphysics?

Summary and Conclusion

- Setting these questions aside, this paper was aimed at showing that there currently is no consensus about which is the best realist quantum theory because there is no consensus about which should be a theory's desiderata (connected to the type of explanation they provide)
- If so, not only there is no consensus now, but likely there never be one in the future

Thank you!