Quantum Scientific Realism

Or How Everyone Learned to Stop Worrying and Love Quantum Mechanics

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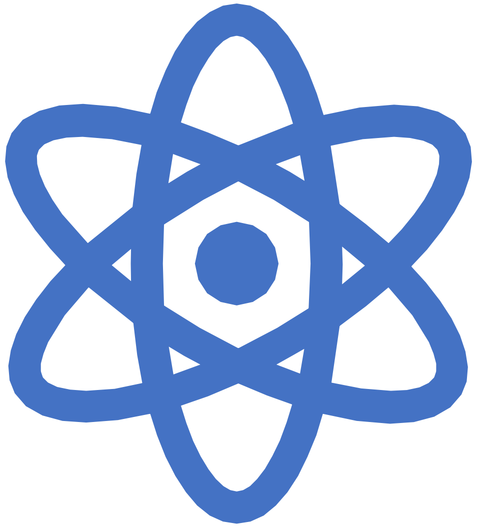
Dr. Strangelove

Or: How I Learned To Stop Worrying And Love The Bomb

Quantum Scientific Realism



Or How Everyone Learned to Stop Worrying and Love Quantum Mechanics

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Punchline

- Many who call themselves realist have actually “stop worrying” and have been seduced by quantum mechanics and the measurement problem (understood as the problem of precisely eliminating macroscopic superpositions).
- ***The measurement problem is a problem for the instrumentalist, and realists should have never considered it.***
- Three types of understanding what being a realist means:
  - Robust: dynamical, constructive explanation (primitive ontology-style approaches)
  - (Radical) Relaxed: principles constraining the macroscopic phenomena (IT-type of approaches)
  - Hybrid (non-radical relaxed): unconventional dynamical explanation, principles constraining the macroscopic phenomena (wave function realism)
- If you are a robust realist, then you should care about completing quantum theory, not solving the measurement problem.
- If you are a relaxed realist, then you do not need to solve the measurement problem ‘precisely.’
- If you are a non-radical relaxed realist, then you are in the middle, and you have no reasons at all to care!

Outline

- The realism problem: QM is incompatible with scientific realism. But how should we fix QM exactly?
- We need to solve one of these three problems: empirical adequacy problem (no macro superpositions), precision problem (the measurement problem), the completeness problem (the wf is not a physical field)
- Correspondingly, we are one of these three types of realism: relaxed (weak), hybrid, robust (strong)
- Each of them correspond to a privileged type of explanation: dynamical, hybrid, kinematic
- No matter where exactly you fall, ***if you are a realist, you have no reason to worry about the measurement problem.***

Quantum theories and scientific realism

- Copenhagen view of QM:
  - QM is unable to provide a microscopic description of the world
  - What it gives us instead is merely a recipe for predicting experimental results.
- As such, it is incompatible with scientific realism, the view that theories can give us information about the nature of the world
  - Let us call this incompatibility ***the realism problem***
- Traditionally: the realism problem is taken to be the measurement problem
- However, there is no unique way of thinking where the realism problem lies, as different people find the problem to be different….

Physics books

- Go back to the bare-bone formalism....
- Physical systems are described by the wavefunction ψ
    - It evolves according to the Schrödinger equation
    - Any solution of this equation describes possible states of affairs which are observed to happen
    - The Schrödinger equation is a wave equation (in particular, mathematically, it is linear), so that any sum of solutions of this equation is a solution itself
        - Nothing particularly striking or problematic in this, as it is just a regular feature of equations describing waves: waves superimpose with one another (think of how, for instance, water waves in a pond can interfere with one another creating different wave patterns)

The measurement problem as a problem of empirical adequacy

- Now here is the measurement problem, first version:
- if the wave function describes everything, and it evolves linearly according to the Schrödinger equation, then measurements will have no definite results.
  - The superposition of all possible results is also a possible result.
  - However, we never observe more than one result for each experiment: the pointer of the apparatus always points in a definite direction.
  - In this way, the measurement problem is a problem of empirical adequacy: the theory does not match what we observe.
  - Traditional (Copenhagen) way out: von Neumann's collapse of the wave function.

The measurement problem as a problem of precision

- However, many people find von Neumann's collapse postulate unsatisfactory:
  - it is unclear when one is supposed to apply it, and why it applies.
- In other words, for some the measurement problem also is a problem of precision (most people have this in mind when they talk about the measurement problem):
  - The adequacy problem shows us we need to eliminate unobserved macroscopic superpositions, but we need to eliminate them by using a rule which does not rely on the notion of observer and measurement, because observers and measurements are thought to be physical objects are processes like any other.
  - How do we do this?

The measurement problem as a problem of precision: solutions

- The solutions of the problem of precision are found by observing that the tension is between:
  - a) measurements having definite results (no macroscopic superpositions ever being observed),
  - b) the wf providing the complete description of every physical system, and
  - c) the wf evolving according to the Schrödinger equation.
- Correspondingly we have three distinct solutions of this precision problem:
  - a) one which grants macroscopic superpositions a physical significance →many worlds theory (MW)
  - b) one which would deny that the wf provides the complete description → pilot wave theory (Bohmian mechanics, BM)
  - c) one which would deny that the wf evolves according to the Schrödinger equation, without making reference to an observer or a measurement → spontaneous localization theory or Ghirardi Rimini Weber theory (GRW)

The measurement problem as a problem of completeness

- However, there is another possibility:
- the realism problem is that quantum theory is fundamentally incomplete, as it is a theory of the wf, which is not suitable to describe a physical field
- If so, even if one solves the measurement problem thought as the problem of precision (namely the problem of getting rid, precisely, of the macroscopic superpositions) still this does not necessarily give us a satisfactory theory:
  - In fact, one may solve the precision problem without solving the completeness problem, and solving this problem is considered to be necessary to arrive to a theory compatible with realism.
  - If so, only solving the precision problem in a particular way (namely by completing quantum theory) will solve the realism problem.
  - To better understand this attitude and where it comes from, let me take a short historical detour…..

The measurement problem as a problem of completeness

- The measurement problem is usually tracked down to Schrödinger's 1935 cat paper, but the fact that quantum mechanics was conceptually problematic was clear much earlier than that.
- In 1926, around the time of the Solvay conference, people were debating about the meaning of the theory
  - Heisenberg's matrix mechanics: a pure mathematical theory to reproduce measurement results without providing any understanding or any intelligible mechanism underlying it
  - Bohr's wave-particle duality thesis: microscopic entities have no definite wave or particle nature to show that we do not have adequate concepts to describe the microscopic world.
  - However, there was a lot of resistance....

The measurement problem as a problem of completeness

- de Broglie proposed a theory of waves and particles.
  - Originally the theory had a particle equation but lacked a wave equation, which was supplied by Schrödinger in 1926, with his now-called Schrödinger equation. However, Schrödinger got rid of the particles, presumably because he wanted to provide a purely wave account of matter.
- Schrödinger's wave theory was accepted with enthusiasm by people like Einstein and Lorentz because it left some room for a realist understating.
- Nonetheless Lorentz complained that he would be obliged to go back to matrix mechanics if Schrödinger could not solve what he thought was a fundamental problem:
  - For a many-particle system the wavefunction is not in three-dimensional space but it is in configuration space, namely the space of configurations of all particles. By definition, configuration space is $3N$ dimensional. If the wf provides the description of physical system, this fact would make it a wave in configuration space, rather than in 3d space, and this was considered unacceptable: a field like that cannot represent a physical field.

The measurement problem as a problem of completeness

- Here is what Lorentz writes to Schrödinger: “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.”
- Here are similar concerns expressed by Einstein in a letter to Lorentz dated May 1st, 1926: “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.” Similarly, here is an excerpt from a June 18th, 1926 letter that Einstein sent to Paul Ehrenfest: “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.”
- These quotes suggest that the realism problem has already been identified in 1926 as the configuration space problem: the wavefunction is not suitable to represent physical entities because it is a wave in configuration space, regardless of whether there are microscopic or macroscopic superpositions.

The measurement problem as a problem of completeness

- Thus, for them the realism problem is **not** that there are unobserved macroscopic superpositions (the problem of adequacy), and it is **not** that we need a precise rule to get rid of them (the problem of precision).
- The realism problem is a problem of completeness: the wavefunction is not suitable to describe physical objects, so we need something else to do this in its place.
  - Here is Schrödinger, almost ten years before his 1935 cat paper was published: “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.” Also: “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.” Interestingly, this argument can be tracked down historically also to Heisenberg, who has been reported to have said, very vividly, referring to Schrödinger’s work: “Nonsense, [...] space is blue and birds fly through it.” This expresses his unacceptability of a theory with no fundamental three-dimensional fields and with no fundamental three-dimensional physical space.

The measurement problems

- The problem of realism: incompatibility problem between quantum theory and scientific realism
- Three types of measurement problems:
  - 1) empirical adequacy
    - Solution: von Neumann wf collapse
  - 2) precision ('traditional' measurement problem)
    - 3 traditional three solutions (MW, BM, GRW)
  - 3) completeness
    - Solutions:...?.

Different types of realism

- Which of the three measurement problems should be of interest to the scientific realist?
- Two broad kinds of realist attitudes:
  - Relaxed realism (weak realism): a theory is amenable to a realist interpretation if it is able to account for the macroscopic regularities
  - Robust realism (strong realism): a theory is amenable to a realist interpretation if it is able to provide a fundamental, dynamical, microscopic explanation of why such regularities happen.

Robust Realism

- Einstein was convinced that quantum mechanics was incomplete since the 1920s, and it was because of this reason that he thought it is incompatible with realism.
  - He provided the following reasons, in temporal order starting from 1926 until 1935:
    - 1) Configuration space problem: if QM were complete then the wf would be a ‘wave’ in configuration space, which cannot be interpreted as something vibrating, and that is unacceptable.
    - 2) EPR nonlocality argument: if QM were complete then the world would be nonlocal, and that is unacceptable.
    - 3) Schrödinger's cat: if QM were complete then we would have macroscopic superpositions, and that is unacceptable.
  - This view is robustly realist: Einstein was looking for something to account for a microscopic dynamics to explain why the quantum rules work.

Robust Realism

- Both Einstein and Schrödinger wanted to make quantum mechanics compatible with scientific realism by providing a fundamental, microscopic, description of the quantum world, rather than merely suppress the macroscopic superpositions.
- Thus, the spontaneous localization theory and the many-worlds theory would **not be an option** for them
- Primitive ontologists follow Einstein and Schrödinger in this attitude (see later)
- Instead, as we will see, a relaxed realist would not necessarily look for any additional information to complete the description of the wf.

Radical Relaxed Realism

- Traditionally, realism is contrasted with instrumentalism:
  - While instrumentalists care only about reproducing experimental outcomes, realists care about understanding the nature of reality which gives rise to such outcomes.
  - Realists also advocate that one needs to solve the precision problem in order to have information about the nature of reality from quantum theory.
- However, there are those who call themselves realists without seeing any need of solving the precision problem:
  - They think the problem is merely the one of empirical adequacy, and thus they find nothing wrong with the solution provided by von Neumann.
  - They take the orthodox view at face value, and then trying however to make realist sense of it. These can be thought of a radical variety of the class I have dubbed relaxed realist.

Radical Relaxed Realism

- Information-theoretic (IT) interpretation of quantum theory (Bub and Pitowsky)
  - Basic idea: quantum theory is to be understood as laying out a set of constraints imposed on the empirical data.
  - They are realist: these data exist objectively and mind-independently, but they do not think they need to tell any additional story about how these data are generated.
- Rainforest realism (Ladyman and Ross)
  - Basic idea: objects, both at the microscopic and the macroscopic level, are seen as real patterns, defined by their usefulness. Measurement devices and measurement results are not analyzed in terms of more fundamental entities (there aren't any) but they are understood as effective descriptions.

Radical Relaxed Realism

- Usual reaction from the realist camp:
  - these attempts are ‘not realist enough,’ they are borderline instrumentalist.
- However, the radical relaxed realists will not deny, like the more traditional instrumentalist, that physical theories are not the kind of things which can give us a description of what is unobservable.
  - Rather they will say that a microscopic description is NOT NEEDED to make the explanation satisfactory.

Moderate Relaxed Realism

- Middle position:
  - Someone may ask for more, without however necessarily going robust:
    - someone could still care about the adequately reproducing the phenomena, but she could also care about having all physical objects and processes being governed by a unified, precise dynamics.
  - In other words, one would like to have an equation of motion for both the fundamental entities (micro) and the measurement processes (macro)
    - So, while for the radical relaxed realists we just saw the realism problem as the adequacy problem dissolves when adopting the collapse rule, for this other type of non-radical or moderate relaxed realists there is still the problem of precision.
    - This is a realist account, but still relaxed because it deals with the phenomena at the macroscopic level and does not question the wf to be complete.

Moderate Relaxed Realism

- In other words, this is a variety of relaxed realism in which one cares also of the adequacy of the experimental predictions (similarly to the radical relaxed realists), but one solves the measurement problem to make the quantum theory precise as the pilot-wave theory, the spontaneous localization theory, and the many-worlds theory do (contrary to the radical version of relaxed realism)
- This type of non-radical relaxed realism provides a middle ground between the robust realism (which looks for something to complete quantum theory) and the radical relaxed realism (which is content with the collapse rule)

Moderate Relaxed Realism

- However, that it is a very peculiar position to hold:
  - How did a realist end up focusing on the phenomena (macroscopic superpositions) and not on the microscopic dynamics?
  - Instrumentalists care about these things; should not the realist care for more?
- Indeed, this is the position of the robust realism who cares about more than just eliminating macroscopic superpositions:
  - She looks for the microscopic dynamics which generates what we observe at the macroscopic level
  - She uses the measurement problem to make the point that quantum mechanics is fundamentally complete, rather than to claim that it is enough to eliminate the macroscopic superpositions (because for them it is not)
- Now the question is: why think that the measurement problem is the realism problem?

Moderate Relaxed Realism

- In other words, it seems that **the measurement problem is fundamentally a problem for the instrumentalist, rather than for the realist**
  - This is somewhat paradoxical, because it is the realist who brings up the measurement problem as a problem for quantum theory.
- That the measurement problem is an instrumentalist problem is clear by noticing its name:
  - it is a problem of which measurement outcomes we could observe, not a problem about why we observe them.
  - We do not worry about what kind of microscopic description could give rise to such macroscopic measurement outcomes

Summing up …

- Robust realists: the realism problem is the completeness problem
- Radical relaxed realists: the realism problem is the adequacy problem
- Non-radical relaxed realists: the realism problem is the precision problem

Type of Realism	Type of Problem	Acceptable Theory
Robust	Completeness	Primitive ontology
Non-radical Relaxed	Precision	Hidden variables, modified Schrödinger dynamics, many-worlds
Radical Relaxed	Adequacy	von Neumann rule

The Big and the Small Measurement Problem

- Pitowsky's distinction between a small and a big measurement problem
  - The big problem = the completeness problem (microscopic, dynamical explanation)
  - The small problem = precision problem (explaining how 'classical' macroscopic measurement outcomes arises from a quantum measurement process)
  - Robust realists require a microscopic dynamics, and thus completing quantum theory, so they focus on the Big problem.
  - Relaxed realists only need to solve the small problem.

Wavefunction Realism

- Traditional story in the philosophy of quantum physics literature:
  - MW and GRW:
    - They are theory about the wf, that is the fundamental equation of QM is an equation of evolution of the wf.
    - So, the wf is the fundamental object of the theory one should be realist about.
    - Just like one was a realist about position in CM because the fundamental equation of classical mechanics was an equation for the temporal evolution of position.
  - This position is called wavefunction realism.

Many worlds

- Which type of realists are many-worlds theorists?
- They are relaxed realists, since the theory only solves the small problem:
  - In fact, the main idea of MW is that there are macroscopic superpositions, but we do not see them because the different terms of the superposition never interact with one another.
  - The alternative outcomes of a measurement process are associated with different branches in the decomposition of the wf.
  - The basic problem is thus to 'save the appearances:'
    - The theory needs to explain how measurements have definite results, and its reply is that they do not.
    - Because of this, the theory only solves the small problem.

Spontaneous collapse theory

- What kind of realist is one endorsing GRW?
  - A natural possibility is wf realism (bare GRW): everything is wf.
  - Since the wf is configuration space, this theory is not a solution of the completeness problem.
  - So bare-GRW theorists are not robust realists.
    - Indeed, the wf realist needs to derive the appearances (three-dimensionality, localization, and regular macroscopic properties) in terms of the wf.

Spontaneous collapse theory

- Two main attempts:
  - a) Albert’s functionalist reduction of 3d microscopic objects from the wf.
    - 1) functionally define 3d microscopic objects;
    - 2) show that the wf can play the role of a 3d object;
    - 3) compose macroscopic objects from these ‘3d microscopic objects’
  - b) Ney instead proposes that symmetries can help pick out, among all the possibilities, the three-dimensional world as privileged.

Spontaneous collapse theory

- If so, wf realists are **relaxed realist in denial**:
  - It is clear from their writings that they think of themselves as being robust realists (they call themselves wavefunction realists and they take the wavefunction ‘ontologically seriously’)
  - However, they end up endorsing a position which is too similar to the relaxed realist that they would arguably like:
    - in fact, they reproduce appearances and systematize the phenomena just as the relaxed realists do.

Pilot wave theory

- Many wf realists find the pilot-wave theory not very compatible with to their view:
  - Ontology
    - 1: N particles in 3d + 1 wave in 3N-d
    - or
    - 2: 1 ‘particle’ and 1 ‘wave’ in 3N-d?
    - If 1, then how do the particle and the wave interact?
      - Communication problem
    - If 2, then we still have the configuration space problem and we (seem to) lose the motivation of the theory:
      - Why add particles if you can do it with the wave alone?

Pilot wave theory

- A better way of understanding this theory (the primitive ontology – PO-approach):
  - The pilot wave theory is about particles in 3d , the wf DOES NOT REPRESENT MATTER
  - Underlying assumption:
    - The realism problem is the incompleteness problem:
      - one always needs an ontology represented by a mathematical object in three-dimensional space because, given that the wavefunction is a field in configuration space, it cannot represent the ontology of quantum theory
    - Therefore, all quantum theories are incomplete:
      - They ALL should be thought as 'hidden variable' theories, in the sense that matter needs to be described by something else (in three-dimensional space) and not by the wf.

Pilot wave theory

- If one grants that quantum theory is complete, then one can complete however she wants:
  - The pilot-wave theory is arguably the simplest way of doing this
  - But it is not the only way to go: GRWm, GRWf, GRWx…

  - **These are all solutions of the realism problem seen as the <u>incompleteness</u> problem, not of the precision problem.**

Pilot wave theory

- What is the wf?
  - it is not an expression of our ignorance like in some epistemic approaches (such as IT)
  - Rather, it is best seen as law-like:
    - The role of the wf is to help implementing the law governing the spatio-temporal trajectories of matter PO.
    - This view fits particularly well with a Humean account of laws, since the wf is part of the axioms.

Principle Theories, Constructive Theories and Scientific Realism

- Principle (or kinematic) theories are formulated in terms principles, which are used as constraints on physically possible processes, as in thermodynamics (e.g. ‘no perpetual motion machines’).
- Constructive theories involve the dynamical reduction of macroscopic objects in terms of the motion and interactions of their microscopic constituents.
  - An example of a principle theory is thermodynamics, and an example of constructive theory is statistical mechanics, which reduces the behavior of gases to the motion of atoms

Principle Theories, Constructive Theories and Scientific Realism

- ”In a theory of principle […] one explains the phenomena by showing that they necessarily occur in a world in accordance with the postulates. Whereas theories of principle are about the phenomena, constructive theories aim to get at the underlying reality. In a constructive theory one proposes a (set of) model(s) for some part of physical reality […]. One explains the phenomena by showing that the theory provides a model that gives an empirically adequate description of the salient features of reality.” Yuri Balashov and Michel Janssen

Principle Theories, Constructive Theories and Scientific Realism

- Einstein introduced this distinction to criticize his 1905 formulation of relativity theory, a principle theory based on two principles:
  - 1) equivalence of inertial frames for all physical laws, and 2) constancy of the velocity of light
- This theory explains relativistic effects (such as length contraction and time dilation) as the physical phenomena compatible with the theory's principles
- By contrast, Lorentz's theory (1909) derives the relativistic effects from the electromagnetic properties of the aether and its interactions with matter, and because of this is a constructive theory

Principle Theories, Constructive Theories and Scientific Realism

- Again, in the worlds of Balashov and Janssen:
- “Consider the phenomenon of length contraction. Understood purely as a theory of principle, SR [special relativity] explains this phenomenon if it can be shown that the phenomenon necessarily occurs in any world that is in accordance with the relativity postulate and the light postulate. By its very nature such a theory-of-principle explanation will have nothing to say about the reality behind the phenomenon. A constructive version of the theory, by contrast, explains length contraction if the theory provides an empirically adequate model of the relevant features of a world in accordance with the two postulates. Such constructive-theory explanations do tell us how to conceive of the reality behind the phenomenon.”

Principle Theories, Constructive Theories and Scientific Realism

- However, Einstein could have said something similar for quantum theory:
  - QM with the collapse postulate can be seen as principle theories.
    - Indeed, the IT approach explicitly accepts this.
  - However, someone like Einstein would think of QM as a phenomenological theory:
    - We need a microscopic dynamical explanation of such phenomena.

Principle Theories, Constructive Theories and Scientific Realism

- A robust realist (like Einstein, or the primitive ontologists) would favor constructive theories, would regard quantum theory to be incomplete, and thus would like to solve the 'big' measurement problem.
- A radical relaxed realist (like Bub and Pitowsky) would instead favor principle theories, and would regard the realism problem as the 'small' measurement problem.
- What about the non-radical relaxed realist, like wavefunction realists?

Principle Theories, Constructive Theories and Scientific Realism

- One the one hand the wf realists claim they are robust realists, as they wish to find an understanding of the fundamental reality
  - If so, the theory they propose should be constructive.
  - And this would require a dynamical derivation of the quantum rules (the principles) in terms of the fundamental (microscopic and 3d) ontology.
- But the explanation of the macroscopic phenomena in is instead fundamentally non-constructive, as wf realists provide principles that would need to constrain the phenomena:
  - Albert constrains them by postulating what the Hamiltonian needs to be, and Ney constrains them by postulating that certain symmetry properties should hold.

Principle Theories, Constructive Theories and Scientific Realism

- However, wf realists does not provide with a principle theory either, as they DO care about the dynamics:
  - The precision problem motivated to have a precise equation for the dynamics at all scales.
  - Albert’s functionalist account uses the dynamics even if not constructively, using the form of the Hamiltonian (rather than its solutions) to ‘recover’ 3d.
- Having a non-constructive explanation and giving importance to the dynamics seem to pull in opposite directions:
  - The former pushes towards radical relaxed realism, while the latter towards robust realism, making wf realism a peculiar hybrid.

Principle Theories, Constructive Theories and Scientific Realism

Type of Realism	Type of Problem	Acceptable Theory	Type of Explanation
Robust	Completeness	Primitive ontology	Constructive/dynamical
Non-radical Relaxed	Precision	Hidden variables, modified Schrödinger dynamics, many-worlds	Non-constructive/dynamical
Radical Relaxed	Adequacy	von Neumann rule	Principle/kinematic

The measurement problem?!

- Radical relaxed realism:
- One could maintain that there in no more to realism than radical relaxed realism, namely that we should be satisfied with constraining and systematizing the phenomena, and that the other approaches are redundant (IT APPROACH)
  - If so, then the radical relaxed realist is correct it their distinction between big and small problem
  - And that ***one should aim at solving the small problem (the adequacy problem), rather than the measurement problem*** (=the problem of precisely eliminating the macroscopic superpositions)

The measurement problem?!

- Robust realism
- Otherwise, one could argue that the robust version of realism is the one which truly capture the spirit of scientific realism, while the relaxed version is too weak (PRIMITVE ONTOLOGY APPROACH)
  - If so, then the robust realist puts too much focus on the measurement problem (=the problem of precisely eliminating the macroscopic superpositions)
- A robust realist should think that quantum mechanics is just like thermodynamics, and she should look for its corresponding dynamical, microscopic explanation:
  - The spontaneous localization theory and the many-worlds theory (2 out of 3 solutions of the measurement problem) **do not** provide a dynamical explanation but merely a set of principles to constraint the phenomena → ***these theories should not have been considered by the robust realist in the first place .***

The measurement problem?!

- Non-radical Relaxed realism
- Alternatively, one could maintain that a realist could look for a fundamental (rather than microscopic) reality beyond the phenomena (WAVEFUNCTION REALISM)
- However, this is a hybrid view and because of this, the wf realist finds herself to face two connected challenges….
- 1) There is a tension between the desire of the wf realist of robust realism, and the kind of explanation the theory provides, which is not in constructive terms:
  - She starts off as a robust realist, but she ends up too close to the IT approach that she presumably would have liked.
  - If so, one may wonder: ***what the point of solving the measurement problem is, if one can do without it, as the IT approach does?***

The measurement problem?!

- Arguably, the point of solving the measurement problem is the problem of precision: we want a precise rule to specify the wavefunction collapse.
- But why would one want a precise rule if she cares only about the appearances?
  - It seems one will care about the precision of the rule ultimately if she cares about the dynamics: it is because one wishes a unified dynamics which is applicable at all scales that one is interested on theories like the spontaneous localization theory.
  - However, why are wf realists interested in the dynamics, if they provide a non-dynamical explanation?

The measurement problem?!

- 2) there is another tension between their realist desire to read quantum mechanics as a theory about the wf, and their desire of understanding the macroscopic phenomena in terms of the microscopic ones, as it is done in statistical mechanics, in a constructive way.
- In other words, if someone wishes quantum theories to be about the wf only, then she should not be too attached to a constructive understanding.
- However, Albert has defended the statistical mechanics (constructive) explanation of thermodynamics
- In addition, he argued that the same explanatory strategy used in the classical domain would extend in the quantum domain, and that bare GRW, because it is a probabilistic theory, would be better than other deterministic theories.
- The reasoning goes roughly as follows….

The measurement problem?!

- The Boltzmannian approach to statistical mechanics is one in which one suitably derives the macroscopic laws of thermodynamics from the microscopic classical dynamics.
- To do so, one needs three ingredients: the dynamics, the statistical postulate and the past hypothesis.
- Albert argues that in the context of a theory such as (bare) GRW, in which one has the probabilities already in the dynamics, one could dispense of the statistical postulate.
- Because of this reason, bare GRW would provide an understanding of the laws of thermodynamics by relying only on two principles. As a result, bare GRW should be preferred to its deterministic alternatives, as the pilot-wave theory, which still would need three ingredients.

The measurement problem?!

- However, the explanation given by bare GRW is a non-constructive explanation, while the quantum statistical explanation is constructive.
- How are they compatible? Albert would say that first shadows of the wf would form, and then they behave as microscopic 3d objects to which we apply the statistical mechanical machinery as usual.
- However, there are two types of explanations:
  - The formation of the shadows, which is non-constructive, and the constructive statistical mechanical explanations.
- Because of this, the theory seems less simple than the pilot-wave theory, in which all explanations are constructive.

The measurement problem?!

- So…. non-constructive understanding of bare GRW combined with the importance given to the dynamics creates two tensions:
- 1) it is a realist theory only in a relaxed sense. It is not an instrumentalist theory, but it is not robustly realist either: in fact it seems more similar to approaches like the IT interpretation, in which one merely cares about systematizing the phenomena, than many defenders of the theory may like. And it is unclear why one should prefer wf realism to IT: why precise dynamical solution if one does not care about the dynamics?
- 2) it is unclear how to reconcile this non-constructive explanation with the constructive explanation in statistical mechanics, if one wishes to argue that the explanation of the laws of thermodynamics should not substantially change when moving from the classical to the quantum domain

Conclusion

- I have argued that **the measurement problem is a red herring:**
  - It has been proposed by realists to reconcile quantum mechanics with scientific realism
  - But it should have never been considered by realists at all!
  - By focusing on this problem just created a vast amount of confusion, and prevented scientific progress:
    - If you are a radical relaxed realist (like a IT person), you should be happy with the vN rule
    - If you are a robust realist (like a primitive ontologist), you should focus on completion of quantum theory, so you should never have focused on GRW or MW
    - If you are non-radical relaxed realist (like a wf realist), it is unclear what you should focus on:
      - if you care about principle explanations, you should not care about the measurement problem (precision problem) but only the adequacy problem;
      - if you care about the dynamics, then you should care about the completeness problem.

Thank you for your attention!