IPP-QM-15: Pragmatism and relational quantum mechanics

James Read[1]

[1] Faculty of Philosophy, University of Oxford, UK, OX2 6GG

MT24

The course

1. Basic quantum formalism
2. Density operators and entanglement
3. Decoherence
4. The measurement problem
5. Dynamical collapse theories
6. Bohmian mechanics
7. Everettian structure
8. Everettian probability
9. EPR and Bell's theorem
10. The Bell-CHSH inequalities and possible responses
11. Contextuality
12. The PBR theorem
13. Quantum logic
14. QBism
15. Pragmatism and relational quantum mechanics
16. Wavefunction realism

Today

Quantum pragmatism *chez* Healey

Quantum pragmatism *chez* Menon

Relational quantum mechanics

Comparisons

Today

Quantum pragmatism *chez* Healey

Quantum pragmatism *chez* Menon

Relational quantum mechanics

Comparisons

From QBism to pragmatism and RQM

- In the previous lecture, I introduced QBism in some detail.

From QBism to pragmatism and RQM

- In the previous lecture, I introduced QBism in some detail.
- In the first half of this lecture, I'll turn to *quantum pragmatism*.

From QBism to pragmatism and RQM

- In the previous lecture, I introduced QBism in some detail.
- In the first half of this lecture, I'll turn to *quantum pragmatism*.
- The most prominent expositor of quantum pragmatism is Healey, so going forward I will focus mostly on his work (especially (Healey 2017)), although I will also discuss a recent alternative pragmatist proposal by Menon (2024).

From QBism to pragmatism and RQM

- In the previous lecture, I introduced QBism in some detail.
- In the first half of this lecture, I'll turn to *quantum pragmatism*.
- The most prominent expositor of quantum pragmatism is Healey, so going forward I will focus mostly on his work (especially (Healey 2017)), although I will also discuss a recent alternative pragmatist proposal by Menon (2024).
- In the second half of this lecture, I'll turn to *relational quantum mechanics* (*à la* Rovelli).

From QBism to pragmatism and RQM

- In the previous lecture, I introduced QBism in some detail.
- In the first half of this lecture, I'll turn to *quantum pragmatism*.
- The most prominent expositor of quantum pragmatism is Healey, so going forward I will focus mostly on his work (especially (Healey 2017)), although I will also discuss a recent alternative pragmatist proposal by Menon (2024).
- In the second half of this lecture, I'll turn to *relational quantum mechanics* (*à la* Rovelli).
- Finally, I'll briefly compare all three of these approaches to quantum mechanics.

Pragmatist approaches to quantum mechanics

- Pragmatists *agree* with QBists that quantum theory should not be thought to offer a description or representation of physical reality: in particular, to ascribe a quantum state is not to describe physical reality.

Pragmatist approaches to quantum mechanics

- Pragmatists *agree* with QBists that quantum theory should not be thought to offer a description or representation of physical reality: in particular, to ascribe a quantum state is not to describe physical reality.
- But they deny that this makes the theory in any way *subjective*—so, e.g., they deny the subsequent QBist claim that the quantum state has to do with *just* subjective probabilities.

Pragmatist approaches to quantum mechanics

- Pragmatists *agree* with QBists that quantum theory should not be thought to offer a description or representation of physical reality: in particular, to ascribe a quantum state is not to describe physical reality.
- But they deny that this makes the theory in any way *subjective*—so, e.g., they deny the subsequent QBist claim that the quantum state has to do with *just* subjective probabilities.
- Rather, quantum mechanics is *objective* on the pragmatist account not because it faithfully mirrors the physical world, but rather because every individual's use of the theory is subject to objective standards supported by the common knowledge and goals of the scientific community.

Pragmatist approaches to quantum mechanics

- Pragmatists *agree* with QBists that quantum theory should not be thought to offer a description or representation of physical reality: in particular, to ascribe a quantum state is not to describe physical reality.
- But they deny that this makes the theory in any way *subjective*—so, e.g., they deny the subsequent QBist claim that the quantum state has to do with *just* subjective probabilities.
- Rather, quantum mechanics is *objective* on the pragmatist account not because it faithfully mirrors the physical world, but rather because every individual's use of the theory is subject to objective standards supported by the common knowledge and goals of the scientific community.
- This is where the pragmatist element comes in (in the philosophy of language sense of pragmatism about truth, meaning, etc.)

Richard Healey

Healey's pragmatist approach

- On Healey's approach (2017, 2022), quantum states are objective, though a true quantum state assignment does not describe or represent the condition or behaviour of a physical system.

Healey's pragmatist approach

- On Healey's approach (2017, 2022), quantum states are objective, though a true quantum state assignment does not describe or represent the condition or behaviour of a physical system.
- Rather: "On this approach, quantum theory is not about agents or their states of belief: and nor does it (directly) describe the physical world. It is a source of objectively good advice about *how* to describe the world and what to believe about it as so described." (Healey 2022, my emphasis)

Healey's pragmatist approach

- On Healey's approach (2017, 2022), quantum states are objective, though a true quantum state assignment does not describe or represent the condition or behaviour of a physical system.
- Rather: "On this approach, quantum theory is not about agents or their states of belief: and nor does it (directly) describe the physical world. It is a source of objectively good advice about *how* to describe the world and what to believe about it as so described." (Healey 2022, my emphasis)
- "Born probabilities are neither credences nor frequencies. They are objective because they are authoritative." (Healey 2022)

Healey and QBism

- Healey co-opts some QBist strategies for dissolving the measurement problem and removing worries about non-locality...

Healey and QBism

- Healey co-opts some QBist strategies for dissolving the measurement problem and removing worries about non-locality...
  - No measurement problem because quantum state not representational.

Healey and QBism

- Healey co-opts some QBist strategies for dissolving the measurement problem and removing worries about non-locality...
  - No measurement problem because quantum state not representational.
  - No worries about non-local state collapse in EPR scenarios, because quantum state not representational.

Healey and QBism

- Healey co-opts some QBist strategies for dissolving the measurement problem and removing worries about non-locality...
  - No measurement problem because quantum state not representational.
  - No worries about non-local state collapse in EPR scenarios, because quantum state not representational.
- ...but he rejects the accompanying subjectivism about quantum states, Born probabilities, and measurement outcomes.

Objections to quantum pragmatism *chez* Healey

Let's now canvas some objections to quantum pragmatism *chez* Healey. In particular, I'll focus upon the following objections:

Objections to quantum pragmatism *chez* Healey

Let's now canvas some objections to quantum pragmatism *chez* Healey. In particular, I'll focus upon the following objections:

A. Quantum pragmatism and explanation.
B. Worries about ontology.
C. Worries about probability.

Objection A: Quantum pragmatism and explanation

The worry about scientific explanation for the quantum pragmatist is quite similar to that for the QBist:

Objection A: Quantum pragmatism and explanation

The worry about scientific explanation for the quantum pragmatist is quite similar to that for the QBist:

> *Many explanations according to this approach to quantum theory seem to at least partially black-box crucial information about the physical ground for the appropriate assignment of quantum states or applications of the Born rule. [...] neither quantum states nor the Born rule can act as initial explanatory input.* (Jansson 2020, p. 165)

Healey's response to the explanation worry

Here is Healey's response to the explanation worry:

Healey's response to the explanation worry

Here is Healey's response to the explanation worry:

> *The primary target of an explanatory application of quantum theory is not a collection of events but a probabilistic phenomenon they manifest. [...] Since the* explanandum *is not itself a physical condition, it is inappropriate to demand a physical* explanans *(such as a physically real quantum state).* (Healey 2022)

Healey's response to the explanation worry

Here is Healey's response to the explanation worry:

> *The primary target of an explanatory application of quantum theory is not a collection of events but a probabilistic phenomenon they manifest. [...] Since the* explanandum *is not itself a physical condition, it is inappropriate to demand a physical* explanans *(such as a physically real quantum state).* (Healey 2022)

Is this really so? And can't we do better?

Healey’s response to the explanation worry

Here is Healey’s response to the explanation worry:

> *The primary target of an explanatory application of quantum theory is not a collection of events but a probabilistic phenomenon they manifest. [...] Since the* explanandum *is not itself a physical condition, it is inappropriate to demand a physical* explanans *(such as a physically real quantum state).* (Healey 2022)

Is this really so? And can’t we do better?

And (as in the case of QBism, see previous lecture), doesn’t this witness some reneging on the possibility of constructive explanations of observed quantum phenomena?

Objection B: Pragmatism and ontology

Worries about ontology on quantum pragmatism *à la* Healey are also somewhat akin to those for QBists:

Objection B: Pragmatism and ontology

Worries about ontology on quantum pragmatism *à la* Healey are also somewhat akin to those for QBists:

- In Healey's account, a central role is played by what we might call 'non-quantum physical magnitudes' (NQPMs), which Healey regards as the representational content of a physical description (as opposed to the quantum state, amplitudes etc., which are to be understood as expert advice to an agent as to what beliefs to have as to the values of the NQPMs).

Objection B: Pragmatism and ontology

Worries about ontology on quantum pragmatism *à la* Healey are also somewhat akin to those for QBists:

- In Healey's account, a central role is played by what we might call 'non-quantum physical magnitudes' (NQPMs), which Healey regards as the representational content of a physical description (as opposed to the quantum state, amplitudes etc., which are to be understood as expert advice to an agent as to what beliefs to have as to the values of the NQPMs).
- These are somewhat akin to QBists' (broadly) ineffable basic ontology.

Objection B: Pragmatism and ontology

Worries about ontology on quantum pragmatism *à la* Healey are also somewhat akin to those for QBists:

- In Healey's account, a central role is played by what we might call 'non-quantum physical magnitudes' (NQPMs), which Healey regards as the representational content of a physical description (as opposed to the quantum state, amplitudes etc., which are to be understood as expert advice to an agent as to what beliefs to have as to the values of the NQPMs).
- These are somewhat akin to QBists' (broadly) ineffable basic ontology.
- But Healey (2017) is never exactly clear about what this basic ontology of NPQMs is supposed to be—see (Wallace 2020) for a long list of possible options.

Objection C: Probabilities and the status of the Born rule

- Healey maintains that the quantum state offers ‘objectively good advice’ to bet in line with the Born rule.

Objection C: Probabilities and the status of the Born rule

- Healey maintains that the quantum state offers ‘objectively good advice’ to bet in line with the Born rule.
- But the Born rule for probabilities does not follow from the quantum state alone (this, of course, is why Everettians must work so hard to justify it—recall Lecture 8).

Objection C: Probabilities and the status of the Born rule

- Healey maintains that the quantum state offers ‘objectively good advice’ to bet in line with the Born rule.
- But the Born rule for probabilities does not follow from the quantum state alone (this, of course, is why Everettians must work so hard to justify it—recall Lecture 8).
- So how is this working? Why not some other probability measure?

Objection C: Probabilities and the status of the Born rule

- Healey maintains that the quantum state offers ‘objectively good advice’ to bet in line with the Born rule.
- But the Born rule for probabilities does not follow from the quantum state alone (this, of course, is why Everettians must work so hard to justify it—recall Lecture 8).
- So how is this working? Why not some other probability measure?
- Healey could appeal to past evidence of the community to justify the Born rule being the ‘objectively good advice’—but then what underwrites this is past evidence, not the quantum state *per se*.

Objection C: Probabilities and the status of the Born rule

- Healey maintains that the quantum state offers 'objectively good advice' to bet in line with the Born rule.
- But the Born rule for probabilities does not follow from the quantum state alone (this, of course, is why Everettians must work so hard to justify it—recall Lecture 8).
- So how is this working? Why not some other probability measure?
- Healey could appeal to past evidence of the community to justify the Born rule being the 'objectively good advice'—but then what underwrites this is past evidence, not the quantum state *per se*.
- Healey *cannot* appeal to the Deutsch-Wallace theorem (see Lecture 8) since he is not a representationalist about the quantum state!

Today

Quantum pragmatism *chez* Healey

Quantum pragmatism *chez* Menon

Relational quantum mechanics

Comparisons

Tushar Menon

Quantum pragmatism *chez* Menon

- In an interesting recent article, Menon (2024) offers a different version of pragmatism to that of Healey.

Quantum pragmatism *chez* Menon

- In an interesting recent article, Menon (2024) offers a different version of pragmatism to that of Healey.
- Drawing on the tradition of ‘inferentialism’ in the philosophy of language (which I won’t go into here—but which is closely related to pragmatism), Menon proposes a halfway house between Healey and Everett:

Quantum pragmatism *chez* Menon

- In an interesting recent article, Menon (2024) offers a different version of pragmatism to that of Healey.
- Drawing on the tradition of 'inferentialism' in the philosophy of language (which I won't go into here—but which is closely related to pragmatism), Menon proposes a halfway house between Healey and Everett:
    1. The quantum state is not representational when decoherence has not occurred.

Quantum pragmatism *chez* Menon

- In an interesting recent article, Menon (2024) offers a different version of pragmatism to that of Healey.
- Drawing on the tradition of ‘inferentialism’ in the philosophy of language (which I won’t go into here—but which is closely related to pragmatism), Menon proposes a halfway house between Healey and Everett:
    1. The quantum state is not representational when decoherence has not occurred.
    2. The quantum state *is* representational when decoherence has occurred—and in those circumstances, it represents an ontology of many worlds.

Menon on his pragmatism

[My view] counts as an interpretation of QM because it resolves the measurement problem. But the mechanics of this resolution is very different from Healey's, which dissolves the measurement problem by denying semantic representationalism. [My view] does not deny semantic representationalism. Instead, it specifies the circumstances under which one should be a semantic e-representationalist about the quantum state: when the correct quantum state assignment is a suitably decohered one. (Menon 2024, p. 21)

Pragmatist problems on Menon’s account

Arguably, Menon’s quantum pragmatism faces the worry about explanation—at least in the situations in which decoherence has not occurred.

Pragmatist problems on Menon's account

Arguably, Menon's quantum pragmatism faces the worry about explanation—at least in the situations in which decoherence has not occurred.

Arguably, Menon's quantum pragmatism faces the worry about ontology—at least in the situations in which decoherence has not occurred.

Pragmatist problems on Menon's account

Arguably, Menon's quantum pragmatism faces the worry about explanation—at least in the situations in which decoherence has not occurred.

Arguably, Menon's quantum pragmatism faces the worry about ontology—at least in the situations in which decoherence has not occurred.

Arguably, Menon's quantum pragmatism does better than that of Healey when it comes to treating the Born probability rule as objective and prescriptive—for, in treating the quantum state as representational when decoherence has occurred, Menon (but not Healey!) can avail himself of (e.g.) the Deutsch-Wallace theorem.

The spectre of Bohr

Menon (personal communication) agrees that his views “are quite close to Bohr, on a charitable reading of Bohr”.

The spectre of Bohr

Menon (personal communication) agrees that his views "are quite close to Bohr, on a charitable reading of Bohr".

But then one is reminded of Saunders' take on Bohr, quoted back in Lecture 4:

> *Bohr insisted that the formalism can only be interpreted by specification of a (classically defined) context of measurement. But there are now plenty of examples of causal spacetime explanations for the phenomena that Bohr considered (as given in all the major realist schools today, whether pilot-wave theory, GRW theory, or the Everett interpretation) [...]* (Saunders 2005, pp. 24-25)

Menon vs wholesale realism

- Challenge for Menon on the basis of Saunders' observations: given that a *fully* realist Everettian approach is available which can help with the explanation and ontology challenges for pragmatism, why not embrace that instead?

Menon vs wholesale realism

- Challenge for Menon on the basis of Saunders' observations: given that a *fully* realist Everettian approach is available which can help with the explanation and ontology challenges for pragmatism, why not embrace that instead?
- To be fair to Menon, he claims that his view *follows* from antecedent commitments (to inferentialism) in the philosophy of language—but then, of course, the view will be persuasive only to those who share those commitments.

Today

Quantum pragmatism *chez* Healey

Quantum pragmatism *chez* Menon

Relational quantum mechanics

Comparisons

Relational quantum mechanics

Let's now change tack, and consider *relational quantum mechanics* (RQM), which has been developed over the past few decades by Rovelli and collaborators (from 1996 onwards).

Relational quantum mechanics

Let's now change tack, and consider *relational quantum mechanics* (RQM), which has been developed over the past few decades by Rovelli and collaborators (from 1996 onwards).

The guiding idea of RQM is that systems only have quantum states *relative* to other systems.

Getting a feel for RQM

- Here's a helpful rule of thumb for RQM (from Faglia (2024)): take unitary quantum mechanics plus collapse ('orthodox QM'), and (a) replace the word 'measurement' with the word 'event', and (b) replace the phrase 'quantum state' with the phrase 'relative quantum state'.

Getting a feel for RQM

- Here's a helpful rule of thumb for RQM (from Faglia (2024)): take unitary quantum mechanics plus collapse ('orthodox QM'), and (a) replace the word 'measurement' with the word 'event', and (b) replace the phrase 'quantum state' with the phrase 'relative quantum state'.
- So RQMists will say things like: "The *relative* quantum state evolves unitarily, except at *events*, where it collapses."

Getting a feel for RQM

- Here's a helpful rule of thumb for RQM (from Faglia (2024)): take unitary quantum mechanics plus collapse ('orthodox QM'), and (a) replace the word 'measurement' with the word 'event', and (b) replace the phrase 'quantum state' with the phrase 'relative quantum state'.
- So RQMists will say things like: "The *relative* quantum state evolves unitarily, except at *events*, where it collapses."
- The basic ontology of RQM is of *systems*, which have *relative quantum states*, and which interact at *events*, at which point the relative quantum states collapse.

Promises of RQM

It's evident from his writings that Rovelli intends RQM to make good on the following desiderata:

Promises of RQM

It's evident from his writings that Rovelli intends RQM to make good on the following desiderata:

1. RQM gives no special significance to agents, measurements or minds.
2. RQM does not assume a classical/quantum divide.
3. RQM does not require one to modify or add anything to the orthodox mathematical framework of QM.
4. RQM does not posit any hidden variables.
5. RQM is a single-world theory.
6. RQM is compatible with the theory of relativity.
7. RQM is applicable in the context of relativistic QM, quantum field theory and quantum gravity.

(List from Faglia (2024).)

Carlo Rovelli and Emily Adlam

Two versions of RQM

Is the occurrence of events absolute?

Two versions of RQM

Is the occurrence of events absolute?

- **Yes:** ‘Absolute RQM’ or ‘Adlam RQM’ (ARQM) (Adlam & Rovelli 2023).
- **No:** ‘Relative RQM’ or ‘Rovelli RQM’ (RRQM) (Rovelli 1997; Smerlak & Rovelli 2007; Rovelli 2018).

Two versions of RQM

Is the occurrence of events absolute?

- **Yes:** ‘Absolute RQM’ or ‘Adlam RQM’ (ARQM) (Adlam & Rovelli 2023).
- **No:** ‘Relative RQM’ or ‘Rovelli RQM’ (RRQM) (Rovelli 1997; Smerlak & Rovelli 2007; Rovelli 2018).

(Terminology from Faglia (2024).)

Faglia on ARQM

According to ARQM, whenever two systems F and S interact, a quantity $\mathcal{V}$ of S takes a value v relative to *F and a quantity $\mathcal{V}'$ of F takes a value v'* relative to *S. I will denote an interaction between two systems S and F with $S - F$ and I will denote the resulting event in which S's quantity $\mathcal{V}$ takes a certain value v relative to F as $e_S^{(F)}(\mathcal{V})$ or $e_S^{(F)}(\mathcal{V} = v)$.* (Faglia 2024, p. 3)

Faglia on ARQM

> *According to ARQM, whenever two systems F and S interact, a quantity $\mathcal{V}$ of S takes a value v* relative to *F and a quantity $\mathcal{V}'$ of F takes a value v'* relative to *S. I will denote an interaction between two systems S and F with $S - F$ and I will denote the resulting event in which S's quantity $\mathcal{V}$ takes a certain value v relative to F as $e_S^{(F)}(\mathcal{V})$ or $e_S^{(F)}(\mathcal{V} = v)$.* (Faglia 2024, p. 3)

To repeat: the events are not themselves system-relative on ARQM; they are absolute!

Faglia on RRQM

According to RRQM, whenever relative to a system W *an interaction between F and S occurs,* relative to W, *a quantity $\mathcal{V}$ of S takes a value v relative to F and,* relative to W, *a quantity $\mathcal{V}'$ of F takes a value v' relative to S. When this second layer of relativity is at play, I will denote an interaction between two systems S and F which occurs relative to W as $[S - F]^W$ and an event in which, relative to W, S's quantity $\mathcal{V}$ takes a certain value v relative to F as $[e_S^{(F)}(\mathcal{V})]^W$ or $[e_S^{(F)}(\mathcal{V} = v)]^W$.* (Faglia 2024, p. 3)

Faglia on RRQM

> *According to RRQM, whenever* relative to a system W *an interaction between F and S occurs,* relative to W, *a quantity $\mathcal{V}$ of S takes a value v relative to F and,* relative to W, *a quantity $\mathcal{V}'$ of F takes a value v' relative to S. When this second layer of relativity is at play, I will denote an interaction between two systems S and F which occurs relative to W as $[S - F]^W$ and an event in which, relative to W, S's quantity $\mathcal{V}$ takes a certain value v relative to F as $[e_S^{(F)}(\mathcal{V})]^W$ or $[e_S^{(F)}(\mathcal{V} = v)]^W$.* (Faglia 2024, p. 3)

To repeat: the events are themselves system-relative on RRQM! Hence, there is a double relativity involved in RRQM.

Quantum theory according to RQM

- According to RQM, the formalism of quantum theory serves to offer probabilistic predictions regarding the occurrence of events and it is applied as follows.

Quantum theory according to RQM

- According to RQM, the formalism of quantum theory serves to offer probabilistic predictions regarding the occurrence of events and it is applied as follows.
- An algebra of operators is assigned to each system, which represent the physical quantities of the system and whose eigenvalues define the possible values that the quantities may take.

Quantum theory according to RQM

- According to RQM, the formalism of quantum theory serves to offer probabilistic predictions regarding the occurrence of events and it is applied as follows.
- An algebra of operators is assigned to each system, which represent the physical quantities of the system and whose eigenvalues define the possible values that the quantities may take.
- Moreover, systems are assigned quantum states *relative to other systems*.

Quantum theory according to RQM

- According to RQM, the formalism of quantum theory serves to offer probabilistic predictions regarding the occurrence of events and it is applied as follows.
- An algebra of operators is assigned to each system, which represent the physical quantities of the system and whose eigenvalues define the possible values that the quantities may take.
- Moreover, systems are assigned quantum states *relative to other systems*.
- We'll denote, again following Faglia (2024), the quantum state of a system S relative to a system F (relative to a system W) as $[|\psi\rangle_S^{(F)}]^W$ (one can drop all the Ws when working with ARQM).

Relative collapse

RQM incorporates the idea of the *relative* collapse of the quantum state:

Relative collapse

RQM incorporates the idea of the *relative* collapse of the quantum state:

> *In RQM, the evolution of the relative quantum states basically follows "orthodox" quantum mechanics, but (relative) collapse occurs at relative events, rather than at "measurement". More precisely, the evolution of the quantum state follows two rules. Consider two systems S and F such that (relative to W) S has a pure quantum state $[|\psi(t)\rangle_S^{(F)}]^W$ relative to F. $[|\psi(t)\rangle_S^{(F)}]^W$ evolves unitarily according to the Hamiltonian as long as S and W do not interact (relative to W). [...] On the other hand, at any interaction resulting in an event $[e_S^{(F)}(\mathcal{V} = v)]^W$, the relative quantum state collapses to the relevant eigenstate $[|\psi\rangle_S^{(F)}]^W \to \frac{\Pi_v |\psi\rangle_S^{(F)}]^W}{\left|\Pi_v |\psi\rangle_S^{(F)}]^W\right|}$, where Π_v is the projector associated with the value v of the quantity $\mathcal{V}$.* (Faglia 2024, p. 5)

Relative Born rule

We also have the *relative* Born rule:

> ***Relative Born Rule:*** *At an interaction (relative to W) between two systems F and S (i.e. $[F - S]^W$), (relative to W) the probability relative to F for a quantity $\mathcal{V}$ of a system S to take on the value v relative to F is given by Born Rule on the quantum state of S relative to F (relative to W).*

Aside: RQM and the measurement problem

- Odolfredi (2023) claims that RQM “dissolves” the measurement problem.

Aside: RQM and the measurement problem

- Odolfredi (2023) claims that RQM "dissolves" the measurement problem.
- He explains that "since in Rovelli's theory ψ is not considered a real object but rather a mere computational tool, nothing physical is literally collapsing in measurement interactions" (p. 7). Instead, collapse is just "an information update relative to a certain agent" (p. 7).

Aside: RQM and the measurement problem

- Odolfredi (2023) claims that RQM "dissolves" the measurement problem.
- He explains that "since in Rovelli's theory ψ is not considered a real object but rather a mere computational tool, nothing physical is literally collapsing in measurement interactions" (p. 7). Instead, collapse is just "an information update relative to a certain agent" (p. 7).
- This seems to be conflating RQM with QBism (on which see the previous lecture).

Response to Odolfredi from Faglia

> *[I]t's worth stressing that collapse is not just 'an information update relative to a certain agent' (*ibid. *p.7) for the simple fact that quantum states hold relative to any system, not just agents. The collapse of the quantum state does not represent an update in an agent's knowledge about a system, rather it represents a change in an* objective *relation between two systems since the quantum state is* objectively *determined by the occurrence of relative events.* (Faglia 2024, p. 11)

Initial questions about RQM

1. What to make of this picture of relative states, relative collapse, and relative Born rule?
2. Can it meet the challenges of ontology and explanation which faced QBists and pragmatists?

Initial questions about RQM

1. What to make of this picture of relative states, relative collapse, and relative Born rule?
2. Can it meet the challenges of ontology and explanation which faced QBists and pragmatists?

These all seem like good and legitimate questions.

Initial questions about RQM

1. What to make of this picture of relative states, relative collapse, and relative Born rule?
2. Can it meet the challenges of ontology and explanation which faced QBists and pragmatists?

These all seem like good and legitimate questions.

For the time being, however, I want to focus on two more issues for RQM:

A. A preferred basis problem for RQM.
B. A worry about the status of *events* in RQM.

Let's address each of these in turn.

Problem A: a preferred basis problem for RQM

- Onto eigenstates of which operator does the relative state collapse at events in RQM?

Problem A: a preferred basis problem for RQM

- Onto eigenstates of which operator does the relative state collapse at events in RQM?
- In the absence of a clear answer to this problem, the approach seems to face a *preferred basis problem*.

Problem A: a preferred basis problem for RQM

- Onto eigenstates of which operator does the relative state collapse at events in RQM?
- In the absence of a clear answer to this problem, the approach seems to face a *preferred basis problem*.
- For more on this worry, see e.g. (Healey 2022).

Problem B: the problem of events

Faglia's (2024) own distinctive challenge for RQM is this:

Problem B: the problem of events

Faglia's (2024) own distinctive challenge for RQM is this:

1. All versions of RQM explain the world in terms of an ontology of systems and events, where an event consists of a variable of a system taking a value relative to another system.

Problem B: the problem of events

Faglia's (2024) own distinctive challenge for RQM is this:

1. All versions of RQM explain the world in terms of an ontology of systems and events, where an event consists of a variable of a system taking a value relative to another system.
2. In order to solve the measurement problem, RQM needs to offer a specification of the circumstances under which events occur.

Problem B: the problem of events

Faglia's (2024) own distinctive challenge for RQM is this:

1. All versions of RQM explain the world in terms of an ontology of systems and events, where an event consists of a variable of a system taking a value relative to another system.
2. In order to solve the measurement problem, RQM needs to offer a specification of the circumstances under which events occur.
3. Current formulations of RQM claim that events occur whenever interactions occur, without defining the notion of interaction in the context of RQM.

Problem B: the problem of events

Faglia's (2024) own distinctive challenge for RQM is this:

1. All versions of RQM explain the world in terms of an ontology of systems and events, where an event consists of a variable of a system taking a value relative to another system.
2. In order to solve the measurement problem, RQM needs to offer a specification of the circumstances under which events occur.
3. Current formulations of RQM claim that events occur whenever interactions occur, without defining the notion of interaction in the context of RQM.
4. Even on the most plausible ways of understanding the notion of interaction (Faglia argues), RQM fails to provide a satisfactory specification for the occurrence of events.

RQM summary

In summary, then, the central idea underlying RQM is that we have relative quantum states, which collapse at events.

RQM summary

In summary, then, the central idea underlying RQM is that we have relative quantum states, which collapse at events.

(These events are themselves absolute on ARQM, and are relative on RRQM.)

RQM summary

In summary, then, the central idea underlying RQM is that we have relative quantum states, which collapse at events.

(These events are themselves absolute on ARQM, and are relative on RRQM.)

As we've seen, however, this invites a number of questions which aren't yet fully resolved:

RQM summary

In summary, then, the central idea underlying RQM is that we have relative quantum states, which collapse at events.

(These events are themselves absolute on ARQM, and are relative on RRQM.)

As we've seen, however, this invites a number of questions which aren't yet fully resolved:

1. What is the relative-state-independent physical ontology?
2. Is the approach explanatory?

A. Does the approach have a preferred basis problem?

B. Is the approach able to provide a clear specification of the circumstances under which events occur?

RQM summary

In summary, then, the central idea underlying RQM is that we have relative quantum states, which collapse at events.

(These events are themselves absolute on ARQM, and are relative on RRQM.)

As we've seen, however, this invites a number of questions which aren't yet fully resolved:

1. What is the relative-state-independent physical ontology?
2. Is the approach explanatory?

A. Does the approach have a preferred basis problem?
B. Is the approach able to provide a clear specification of the circumstances under which events occur?

Evidently, there remains more work for the RQMist to do...

Today

Quantum pragmatism *chez* Healey

Quantum pragmatism *chez* Menon

Relational quantum mechanics

Comparisons

Comparing QBism, pragmatism, and RQM

I want to close with a more direct comparison of QBism, pragmatism, and RQM:

Comparing QBism, pragmatism, and RQM

I want to close with a more direct comparison of QBism, pragmatism, and RQM:

- All three approaches sign up to the quantum state not being (in general and *per se*) representational of physical reality.

Comparing QBism, pragmatism, and RQM

I want to close with a more direct comparison of QBism, pragmatism, and RQM:

- All three approaches sign up to the quantum state not being (in general and *per se*) representational of physical reality.
- For pragmatists and RQMists, the quantum state is nevertheless ‘objective’, in (respectively) a pragmatic/relational way—not so for QBists.

Two further points

- Healey (2022b) objects to RQM on the grounds that its “ontology of relative facts is incompatible with scientific objectivity”. Is this so? Note that his gripes are more with RRQM than ARQM..

Two further points

- Healey (2022b) objects to RQM on the grounds that its "ontology of relative facts is incompatible with scientific objectivity". Is this so? Note that his gripes are more with RRQM than ARQM..
- Glick (2021) suggests that QBism's version of realism can be understood as 'perspectival' and 'normative'. But isn't 'perspectival realism' (cf. Massimi 2022) a better fit for RQM? And isn't 'normative' a better fit for pragmatism?

Summary

Today, I've:

Summary

Today, I've:

1. Presented quantum pragmatism and relational quantum mechanics.

Summary

Today, I've:

1. Presented quantum pragmatism and relational quantum mechanics.
2. Shown that neither approach is fully anti-realist, although both seems evidently to offer a fairly non-standard form of realism.

Summary

Today, I've:

1. Presented quantum pragmatism and relational quantum mechanics.
2. Shown that neither approach is fully anti-realist, although both seems evidently to offer a fairly non-standard form of realism.
3. Seen some of the philosophical worries about and objections to both of these approaches.

Summary

Today, I've:

1. Presented quantum pragmatism and relational quantum mechanics.
2. Shown that neither approach is fully anti-realist, although both seems evidently to offer a fairly non-standard form of realism.
3. Seen some of the philosophical worries about and objections to both of these approaches.

Next time: the ontology of the quantum state: on what space does this object live? What is the fundamental arena of quantum mechanics?

References I

- Emily Adlam and Carlo Rovelli, “Information is Physical: Cross-Perspective Links in Relational Quantum Mechanics”, Philosophy of Physics 1(1), 2023.
- Paolo Faglia, “An Analysis of Relational Quantum Mechanics”, 2024.
- David Glick, “QBism and the Limits of Scientific Realism”, European Journal for Philosophy of Science 11(53), 2021.
- Richard Healey, *The Quantum Revolution in Philosophy*, Oxford: Oxford University Press, 2017.
- Richard Healey, “Quantum-Bayesian and Pragmatist Views of Quantum Theory”, in E. N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy*, 2022a.
- Richard Healey, “Securing the Objectivity of Relative Facts in the Quantum World”, Foundations of Physics 52(4), 2022b.
- Lina Jansson, “Can Pragmatism about Quantum Theory Handle Objectivity about Explanations?”, in S. French and J. Saatsi (eds.), *Scientific Realism and the Quantum*, Oxford: Oxford University Press, pp. 147–67, 2020.

References II

- Michela Massimi, *Perspectival Realism*, Oxford: Oxford University Press, 2022.
- Tushar Menon, “The Inferentialist Guide to Quantum Mechanics”, 2024.
- Ricardo Muciño, Elias Okon, and Daniel Sudarsky, “Assessing Relational Quantum Mechanics”, Synthese 200(5), 2022.
- Andrea Oldofredi, “The Relational Dissolution of the Quantum Measurement Problems”, Foundations of Physics 53(1), 2023.
- Carlo Rovelli “Relational Quantum Mechanics”, International Journal of Theoretical Physics 35(8), pp. 1637–78, 1996.
- Carlo Rovelli “Relational Quantum Mechanics”, 1997.
- Carlo Rovelli, “Space is Blue and Birds Fly Through It”, Philosophical Transactions of the Royal Society A 376, 2018.
- Matteo Smerlak and Carlo Rovelli, “Relational EPR”, Foundations of Physics 37(3), pp. 427–45, 2007.
- David Wallace, “Review of *The Quantum Revolution in Philosophy*, by Richard Healey”, Analysis 80(2), pp. 381–388, 2020.