IPP-QM-15: Pragmatism and relational quantum mechanics

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MT25

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 *à la* Healey

Quantum pragmatism *à la* Menon

Relational quantum mechanics

Comparisons

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- 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.

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- 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

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- "Born probabilities are neither credences nor frequencies. They are objective because they are authoritative." (Healey 2022)

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- ...but he rejects the accompanying subjectivism about quantum states, Born probabilities, and measurement outcomes.

Objections to quantum pragmatism *à la* Healey

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

Objection A: Quantum pragmatism and explanation

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> *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)

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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?

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- 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).

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- 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.

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- Healey *cannot* appeal to the Deutsch–Wallace theorem (see Lecture 8) since he is not a representationalist about the quantum state! (But maybe he wouldn't care, and past evidence is good enough for him?)

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Tushar Menon

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  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

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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.

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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

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- 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.

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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 (2025)): 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'.

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- 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.

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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 (2025, §2).)

Carlo Rovelli and Emily Adlam

Two versions of RQM

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

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(Terminology from Faglia (2025).)

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 2025, p. 3)

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

Faglia on RRQM

> *In RRQM, the occurrence of events itself is relative to a system. More precisely, according to RRQM, whenever an interaction between F and S occurs* relative to a system *W*, 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. I denote an interaction between two systems S and F that occurs relative to W as* $[S-F]^W$ *and an event relative to W in which S's quantity* $\mathcal{V}$ *takes a value v relative to F as* $[e_S^{(F)}(\mathcal{V})]^W$ *or* $[e_S^{(F)}(\mathcal{V}=v)]^W$*.* (Faglia 2025, p. 17)

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

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- 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 (2025), 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

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> *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* $[|\psi\rangle_S^{(F)}]^W \rightarrow \frac{\Pi_v|\psi\rangle_S^{(F)}]^W}{\left|\Pi_v|\psi\rangle_S^{(F)}]^W\right|}$*, where* Π_v *is the projector associated with the value v of the quantity* $\mathcal{V}$*.* (Faglia 2025, p. 4)

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).*

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- This seems to be conflating RQM with QBism (on which see the previous lecture).

Response to Odolfredi from Faglia

> *Odolfredi misses the key issue with RQM's collapse postulate. He is firstly wrong in claiming that collapse is just "an information update relative to a certain agent" (Odolfredi 2023, 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,* which may or may not result in an update of an agent's knowledge. (Faglia 2025, p. 6)

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  - See Laudisa (2001) and Smerlak & Rovelli (2007).

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  - But does this overcome Bell's concerns about 'measurement'?
- No worries about non-locality in EPR-type experiments because only the *relative* quantum state collapses?
  - See Laudisa (2001) and Smerlak & Rovelli (2007).
  - **Question:** How does this compare to other 'local' narratives about EPR, e.g. that from Everettians?

Initial questions about RQM

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These all seem like good and legitimate questions.

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

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

Let's address each of these in turn.

Problem A: a preferred basis problem for RQM

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- 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).

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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.

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- Relatedly, Jacobs & Read (2025) are worried that RQM cannot offer an ‘absolute’ representation of reality; that it is implicated in some kind of extreme perspectivalism/fragmentalism. (Recall these views from IPP-SR.)

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1. What is the relative-state-independent physical ontology?
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Evidently, there remains more work for the RQMist to do...

Today

Quantum pragmatism *à la* Healey

Quantum pragmatism *à la* Menon

Relational quantum mechanics

Comparisons

Comparing QBism, pragmatism, and RQM

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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 a pragmatic/relational way—not so for QBists.

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  (NB: Healey's problem regards how the relativisation of values of quantities in RRQM seems not to allow for communication in RRQM.)
- 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?

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

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