Quantum theory as a method: the epistemic conception of quantum states

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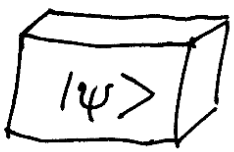
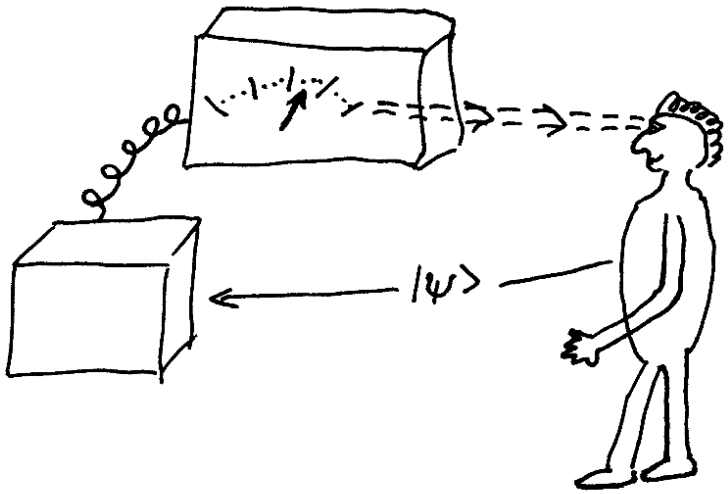
Ontic vs. epistemic accounts of quantum states

Two ways of interpreting states:





The **ontic view** is very natural ...

but much speaks in favour of the **epistemic view**.

Outline of the Presentation

1. Motivating the epistemic conception of states
2. Spelling it out: the “Rule Perspective”

What is the epistemic conception of states?

Basic ideas:

- States are not descriptions of quantum objects.
- States reflect the epistemic conditions of who assigns them.
- There is no such thing as the state a system “is in”.
- Different agents may assign different states to the same system.
- “[D]ensity matri[ces] ... may differ as the nature and amount of knowledge may differ.” (Peierls 1991)

Proponents: Heisenberg (?), Peierls, Mermin, Fuchs, Caves, Schack.

What is the epistemic conception of states?

Further characteristics:

- Quantum theory is regarded as a **method**.
- Notions of “agent” and “measuring” or “encountering” the value of an observable are accepted as primitive,
- justified by comparison of QM to logic and probability theory as methods.

Quantum “paradoxes”

Puzzles that stimulate “interpretations” of quantum theory (Everett, GRW, Bohm, modal,...):

- measurement problem: no measurement outcomes if eigenstate/eigenvalue link is assumed
- non-locality: instantaneous effect on properties of a distant system in case of entanglement

Epistemic conception of states **dissolves** these problems:

Dissolution of paradoxes I: measurement problem

According to the epistemic conception of states: “Measurement collapse” (avoids measurement problem) gets very natural.

- Epistemic situation of experimentalist changes abruptly, **ergo** the state to be assigned must change.
- “Since through the observation our knowledge of the system has changed discountinuously, its mathematical representation also has undergone the discountinuous change ...” (Heisenberg 1958)

Dissolution of paradoxes II: non-locality

Assume preparation procedure leading to assignment of

$$|\psi\rangle = \frac{1}{\sqrt{2}}\left(|+\rangle_A|-\rangle_B - |-\rangle_A|+\rangle_B\right) :$$

- Ontic view: Measurement by Alice (at particle A) has an immediate effect on particle B.
- Epistemic view: Alice's measurement does not change any properties of particle B.
- Only Alice's epistemic situation with respect to B changes.
- After Alice's measurement: Alice and Bob assign different states, and legitimately so!

Quantum Bayesianism

The most prominent version of the epistemic conception today (Fuchs, Caves, Schack, Barnum, Appleby,...)

Main ideas:

- Quantum probabilities are subjective degrees of belief.
- Measurement collapse parallels Bayesian updating.
- There is neither “the” quantum state of a system...
- ...nor is there “the” observable measured in a given setup,...
- ...so there is no such thing as *correctly* assigning a quantum state.

Problem: There **is** “correct” and “incorrect” in quantum state assignment in practice.

Disanalogy between states and observables: States are updated after measurement, observables not.

Rules of state assignment

Solution: Focus on the **rules** that govern state assignment.

- Unitary time-evolution, Schrödinger equation
- Lüders' Rule, measurement collapse
- Entropy maximisation

Proposal for the epistemic conception: These rules apply in different contexts, defined by epistemic situation.

Let's look at the *status* of these rules!

Two sorts of rules

Examples of two different sorts of rules:

- “In order to qualify for the soccer worldcup final, a team should master catenaccio.”
- “In order to qualify for the soccer worldcup final, a team must win one of the woldcup semi-finals.”

More generally:

- Rules as *strategies* or *recommendations* ...
- vs. rules as *defining criteria* (“*constitutive rules*”), Searle 1969

Status of the rules in ontic views

According to the *ontic* conception of states:

- State assignment correct *iff* the true state is assigned.
- Rules of state assignment are guidelines for assigning (some decent approximation to) the true state.
- Notion of a correct state assignment not defined in terms of the rules.
- $\Rightarrow$ Rules are *non-constitutive*.

Status of the rules in the Rule Account

According to – my version of – the *epistemic* conception of states (“Rule Perspective”):

- State assignment correct *iff* in accordance with the rules.
- State assignment in accordance with the rules *means* correct assignment.
- Notion of a correct state assignment defined in terms of the rules.
- $\Rightarrow$ Rules are *constitutive*.

Different agents sometimes *must* assign different states to the same system in order to assign correctly.

Antirealism?

Criticism: This is just old-fashioned Bohr-style antirealism (or instrumentalism)!

Answer:

- Rule Perspective can be called antirealist insofar as it regards quantum theory as non-descriptive.
- But: The Rule Perspective is compatible with realism about structural features of QM formalism.
- Arguably: Antirealism not per se problematic (but obscurantism!).
- Don't forget: All realist alternatives (GRW, Bohm, Everett) have drastic shortcomings!

Generalisability to QFT

Further virtue: Rule Account generalises easily to QFTs/infinitely many degrees of freedom

- Stone-von Neumann theorem was not assumed,
- unitarily inequivalent representations unproblematic,
- existence of pure normal states not required. (See Ruetsche 2004.)

Whether the Rule Perspective is really correct? – The future may show.