Unscrambling the Quantum Omelette

http://tph.tuwien.ac.at/~svozil/publ/2013-Washington-pres.pdf
http://arxiv.org/abs/1206.6024

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Jaynes' Quantum Omelette

"... our present QM formalism is not purely epistemological; it is a peculiar mixture describing in part realities of Nature, in part incomplete human information about Nature — all scrambled up by Heisenberg and Bohr into an omelette that nobody has seen how to unscramble. Yet we think that the unscrambling is a prerequisite for any further advance in basic physical theory. For, if we cannot separate the subjective and objective aspects of the formalism, we cannot know what we are talking about; it is just that simple. So we want to speculate on the proper tools to do this.."

Edwin Thompson Jaynes, *Probability in Quantum Theory* (1990)
http://bayes.wustl.edu/etj/articles/prob.in.qm.pdf

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- all observations are based on detector clicks;
- based on these clicks, and through "projections and conventions" of our mind we reconstruct what we consider the physical universe;

Mind Projection Fallacy according to Jaynes

". . . we are all under an ego-driven temptation to project our private thoughts out onto the real world, by supposing that the creations of one's own imagination are real properties of Nature, or that one's own ignorance signifies some kind of indecision on the part of Nature."

Edwin Thompson Jaynes, *Clearing up Mysteries - The Original Goal* (1989)
http://bayes.wustl.edu/etj/articles/cmystery.pdf

I believe that this sort of "over-interpretation of empirical data" is at the heart of many misconceptions about quantized systems.

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- "experimental proofs" of the Kochen-Specker theorem: "how can you measure a [proof by] contradiction?" (Rob Clifton, 1995);
- physical existence of "counterfactuals;" (Specker's "Infuturabilien" referring to scholastic debates): hypothetical observables that you could have, but did not measure; instead you measured some different, complementary, observable;

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- assumption of a space-time theater in which events occur; rather than the "operationalization" of space-time *via* events.

Part I: Single pure state conjecture

So, how might one be able to "unscramble" the Quantum Omelette?

Try the Kochen-Specker theorem as a guiding principle.

The (strong) Kochen-Specker theorem is usually proven by taking a finite subset of interconnected (the dimension of the vector space must be three or higher for interconnectivity) contexts (=maximal observables=orthogonal bases=unitary operators), and by demonstrating that no two-valued measure (interpretable as classical truth assignment) exists on those structures of observables if noncontextuality is required – meaning that the measure is independent of the context.

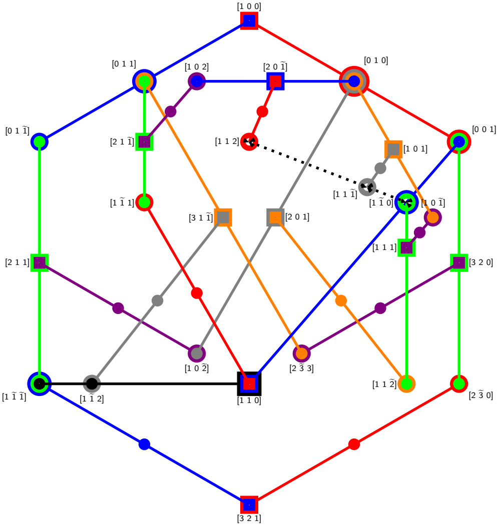
Weaker forms allow two-valued measures, alas too few to be separating some observables; or to allow a homeomorphic embedding into Boolean algebras.

Certified breakdown of value indefiniteness in ACCS theorem

Consider a modified, and, in a particular sense, "improved" version of the Kochen-Specker theorem which certifies "breakdown of (noncontextual) value definiteness" at a particular observable: Let $|a\rangle, |b\rangle \in \mathbb{C}^3$ be unit vectors such that $\sqrt{\frac{5}{14}} \le |\langle a|b\rangle| \le \frac{3}{\sqrt{14}}$. Then there exists a set of projection observables $\mathcal{O}$ containing P_a and P_b, and a set of contexts $\mathcal{C}$ over $\mathcal{O}$, such that there is no admissible assignment function under which $\mathcal{O}$ is non-contextual, P_a has the value 1 and P_b is value definite.

Abbott, Calude, Conder & K.S. (ACCS), DOI: 10.1103/PhysRevA.86.062109, eprint arXiv:1207.2029

Greechie orthogonality diagram of ACCS proof (please see paper for details)



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- quantum random number generator "certified by quantum value indefiniteness:" prepare state $|a\rangle$, measure projector $|b\rangle\langle b|$ (please see ACCS paper for experimental setup for quantum coin tosses);
- While the ACCS theorem certifies only one observable to be value indefinite (given noncontextuality), and while as already pointed out in the ACCS paper, extensions will never be able to go beyond value indefiniteness of all but a "star shaped" configuration of contexts discussed later – the ontological single pure state conjecture suggests to "throw the baby out with the bathwater" by denying the physical co-existence of all but one measuement context prior to measurement: At any given time the system is in a single definite context. In terms of observables, this translates into "ontologically there does not exist any observable beyond the observables representing a single definite context."

Ontological single pure state conjecture cntd.

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- Thereby the ontological single pure state conjecture abandons omniscience: it states that all other (even hypothetically "value definite" yet counterfactual) observables different from the observables associated with the unique state, and possibly ascribed to such a system, are not value definite at all.

Ontological single pure state conjecture cntd.

- Make no mistake: such value indefinite observables may seem to be “measurable” in the sense that their “measurement” yields outcomes; that is, detector clicks. But these outcomes cannot reflect any value definite property of the object prior to measurement because, according to the single pure state conjecture, such a value definite property simply does not exist. Rather the detector clicks associated with the “measurement” might result from properties that also depends *“on the complete disposition of the apparatus”*, as well as on the object, combined.

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- In contradistinction, orthodox quantum mechanics treats all these observables on an equal footing.

What is the formal characterization of a pure quantum state?

Informally, A pure state is characterized by the maximal information encodable into a physical system.

Formally, a pure state can be represented by

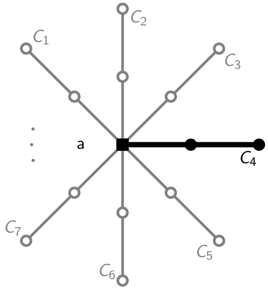
- an orthonormal basis;
- a maximal operator from which all commuting operators can be functionally derived;
- a context, subalgebra or block;
- a unitary transformation (associated with some orthonormal basis).

Phantom contexts and context translation

Phantom context: Any context that is not the single context/state (in which the system is prepared).

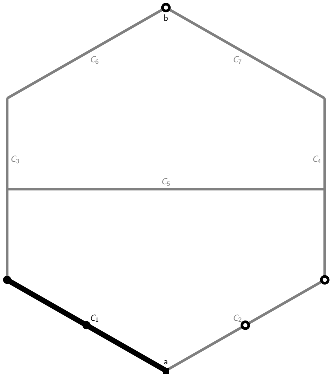
Context translation principle: A mismatch between the preparation and the measurement may result in the "translation" of the original information encoded by a quantum system into the answer requested, whereby noise is introduced by the many degrees of freedom of a suitable "quasi-classical" measurement apparatus.

Ontology of star shaped Greechie diagram of "phantom" contexts



Greechie orthogonality diagram of a star-shaped configuration, representing a common basis element/projector a with an overlaid two-valued assignment reflecting $v(\mathrm{a}) = 1$. Compare also the difference and similarities to Abbott, Calude, Conder & K.S., DOI: 10.1103/PhysRevA.86.062109, eprint arXiv:1207.2029

Specker's "bug" diagram of "phantom" contexts



"Bug-type" Greechie orthogonality diagram with an overlaid two-valued assignment reflecting "$v(\mathrm{a}) = 1$ implies $v(\mathrm{b}) = 0$." This configuration is part of the original proof of the Kochen-Specker theorem. It is assumed that the system is prepared in state C_1, depicted by a block colored in thick filled black; all the other contexts C_2–C_7 are "phantom contexts" colored in gray.

Part II: Persistent Issues

Everett and Wigner's observation of a subjective observer-object cut

Around the same time (in the late 50's), Everett and Wigner observed that, if a unitary (bijective, one-to-one, reversible, Laplacian-type deterministic) quantum evolution were universally valid, then any distinction or cut between the observer and the measurement apparatus necessarily remains not absolute or ontic, but epistemic, subjective and conventional.

Because, suppose that one has defined a cut or difference between an observed quantum and a "quasi-classical" measurement device, one could, at least in principle and if the unitary quantum evolution is universally valid, "draw a larger perimeter." This "enlargement" could contain the entire previous combination, *including* the quantum, the cut, and the measurement device. If the quantum laws are universally valid, such a quantized system should also undergo a unitary quantum evolution. Hence, any "irreversibility" decays into "thin air."

There is no 'emergence' of many-to-one from one-to-one functions; and thus no strictly "irreversible measurement."

If quantum mechanics is universally valid, and if it is governed by unitary, reversible, one-to-one evolution, how does irreversibility arise from reversibility?

Suppose (wrongly) a hypothetical many-to-one function $h(x) = h(y)$ for $x \neq y$ exists which would somehow 'emerge' from injective functions. Any such function would have to originate from the domain of one-to-one functions such that, for all functions f of this class, $x \neq y$ implies $f(x) \neq f(y)$ – or, equivalently, the contrapositive statement (provable by comparison of truth tables) $f(x) = f(y)$ implies $x = y$, a clear contradiction with the assumption.

Indeed, by Caylay's theorem the *unitary transformations* on some Hilbert space $\mathfrak{H}$ form a particular permutation group (consisting of those permutations preserving the inner product), which is a subgroup of the *symmetric group* of all permutations on $\mathfrak{H}$.

Quantum jellification

Alas, without measurement, Schrödinger (in his Dublin seminars 1952) pointed out that quantum theorists should be troubled that, due to the coherent superposition resulting from the co-existence of classically mutually exclusive alternatives, their "surroundings rapidly turning into a quagmire, a sort of a featureless jelly or plasma, all contours becoming blurred, we ourselves probably becoming jelly fish."

The single pure state conjecture and the context translation principle would resolve this conundrum by maintaining that there is only one state "perceived" from many epistemic perspectives; some of them causing noise which FAPP appears irreducible random to intrinsic observers.

Analogues in classical statistical mechanics

Just as Newtonian physics and electromagnetism appear to be reversible, the quantum measurement conundrum is characterized by the reversibility of the unitary quantum evolution.

In this respect, the (ir-)reversibility of quantum measurements bears some analogy to Loschmidt's reversibility paradox – that, for large isolated systems with reversible laws of motion, one should never observe irreversibility, and thus a decrease in entropy – and Zermelo's recurrence objection – that, as an isolated system will infinitely often approach its initial state, its entropy will infinitely often approach the initial entropy and thus cannot constantly increase – in classical statistical mechanics.

And just as in statistical mechanics, irreversibility appears FAPP, yet cannot strictly be true.

Btw, is it in principle possible to produce a mixed state from a pure one?

Again, from a purely formal point of view, it is impossible to obtain a mixed state from a pure one. Because again, any unitary operation amounts to a mere basis transformation or permutation, and this cannot give rise to any increase in stochasticity or "ignorance." Since the generation of "ontologically mixed states" from pure ones would require a many-to-one functional mapping, we conclude that, just as irreversible measurements, genuine "ontological mixed states" originating from pure states cannot exist. Therefore, any ontological mixed state has to be either carried through from previously existing mixed states; if they exist.

If you dont believe me, then I suggest you come up with a concrete experiment that would "produce" a mixed state from a pure one.

Some further speculations regarding quantum random number generators

It is often believed (Born's "1926 inclinations"), that quantum randomness miraculously emerges in a *creatio ex nihilo* from devices which perform in the Laplacian deterministic-unitary regime, such as beam splitters. But how can this happen from unitary transformations alone?

Where does the quantum randomness reside?

I suggest to circumvent this conundrum is by postulating that (i) at every instant, only a single state (or context) exists; and that (ii) through *context translation*, in which a mismatch between the preparation and the measurement results in the "translation" of the original information encoded by a quantum system into the answer requested. Thereby noise is introduced by the many degrees of freedom of a suitable "quasi-classical" measurement apparatus.

Thank you for your attention!