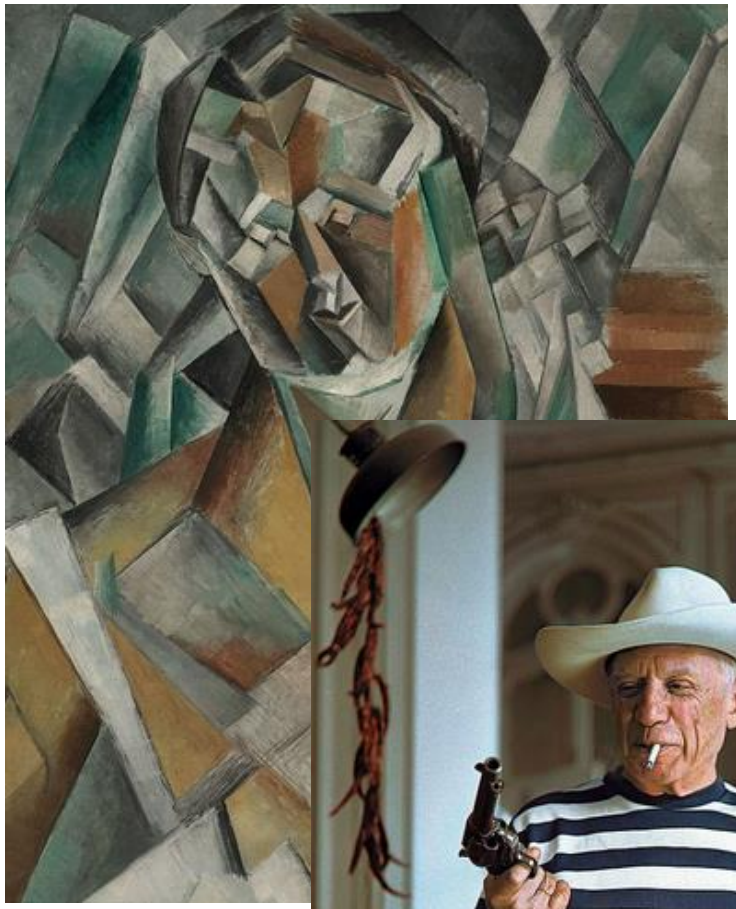
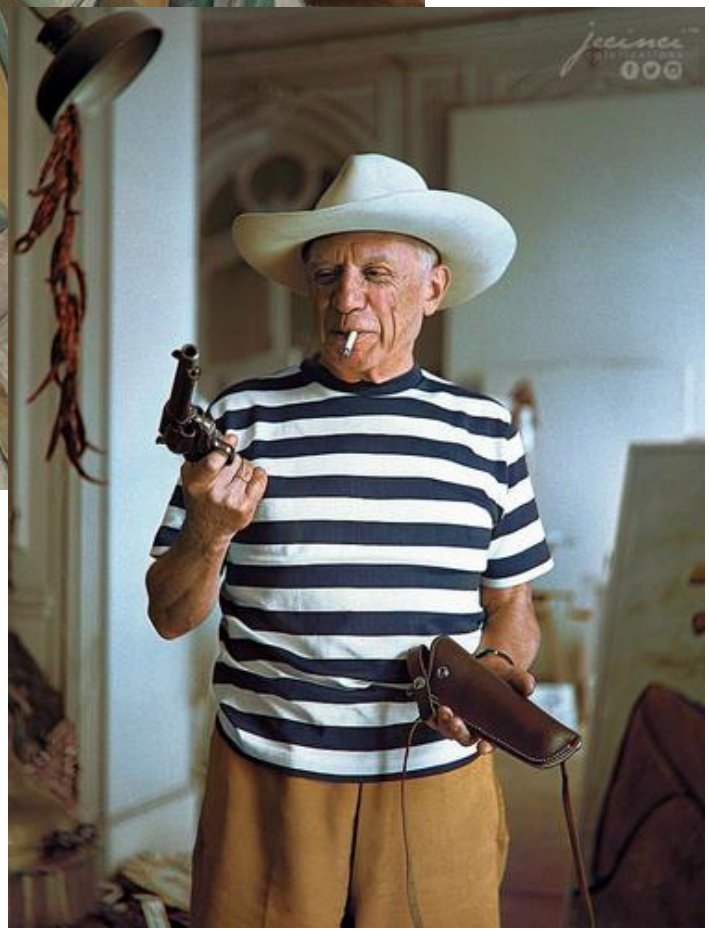




The Day QBism Shot Itself in the Foot

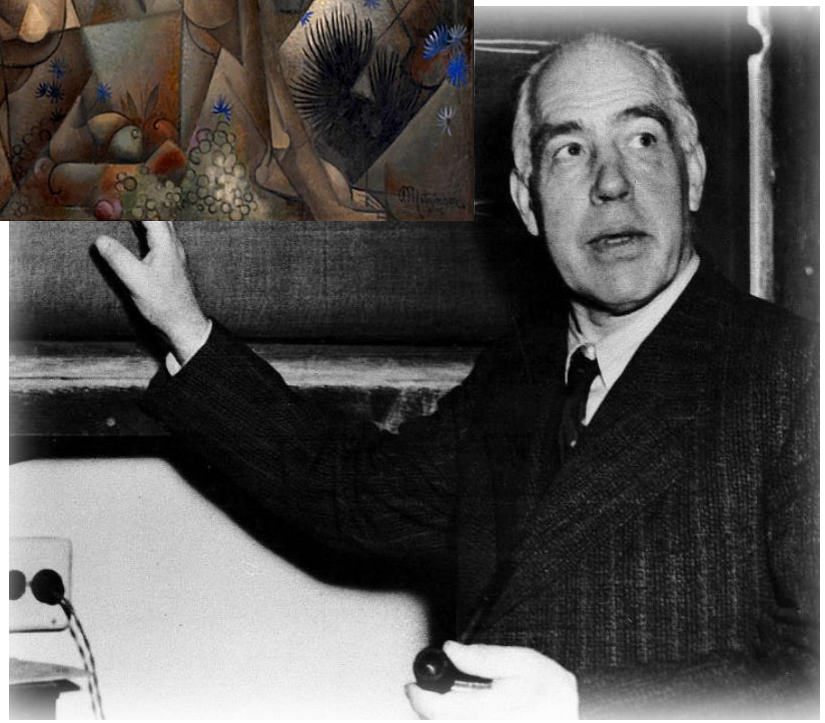
Christopher A. Fuchs

UMass Boston

Notwithstanding Bohr, Three Tenets of QBism

Christopher A. Fuchs

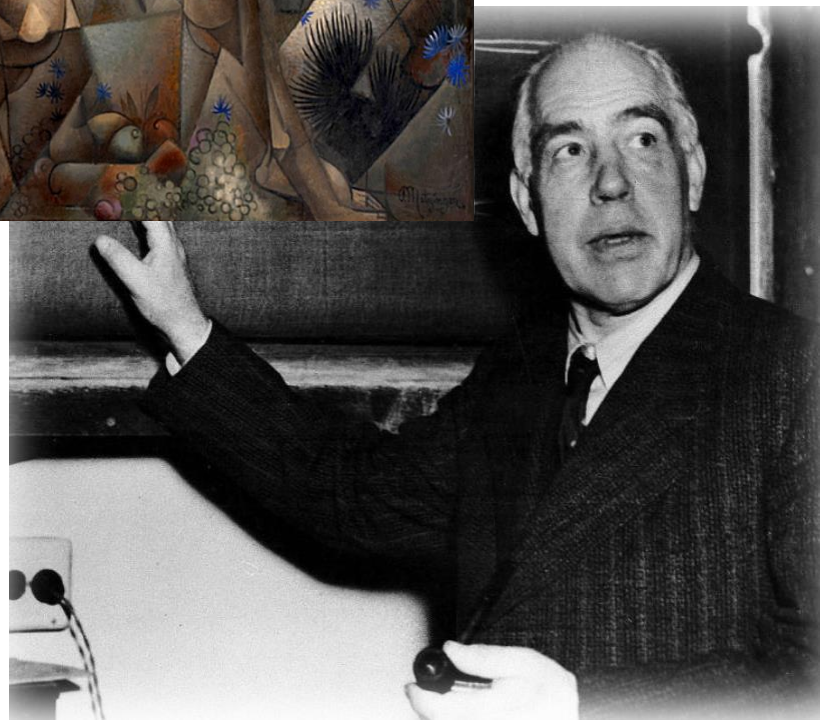
UMass Boston



(84 words)

“Notwithstanding all differences, a certain analogy between the postulate of relativity and the point of view of complementarity can be seen in this, that according to the former the laws which in consequence of the finite velocity of light appear in different forms depending on the choice of the frame of reference, are equivalent to one another, whereas, according to the latter the results obtained by different measuring arrangements apparently contradictory because of the finite size of the quantum of action, are logically compatible.”

Notwithstanding Bohr, Three Tenets of QBism



The day QBism really shot itself in the foot*!*

PHYSICAL REVIEW A, VOLUME 65, 022305

Quantum probabilities as Bayesian probabilities

Carlton M. Caves,[1,*] Christopher A. Fuchs,[1] and Rüdiger Schack[2]
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[2]*Department of Mathematics, Royal Holloway, University of London, Egham, Surrey TW20 0EX, United Kingdom*
(Received 15 August 2001; published 4 January 2002)

In the Bayesian approach to probability theory, probability quantifies a degree of belief for a single trial, without any *a priori* connection to limiting frequencies. In this paper, we show that, despite being prescribed by a fundamental law, probabilities for individual quantum systems can be understood within the Bayesian approach. We argue that the distinction between classical and quantum probabilities lies not in their definition, but in the nature of the information they encode. In the classical world, *maximal* information about a physical



E. T. Jaynes' Vision

1922 – 1998

"Our present QM formalism … 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."

Different People, Different Information.

$$F(p_0, p_1) = \sum_b \sqrt{p_0(b)}\sqrt{p_1(b)}$$

Different People, Different Beliefs*!*

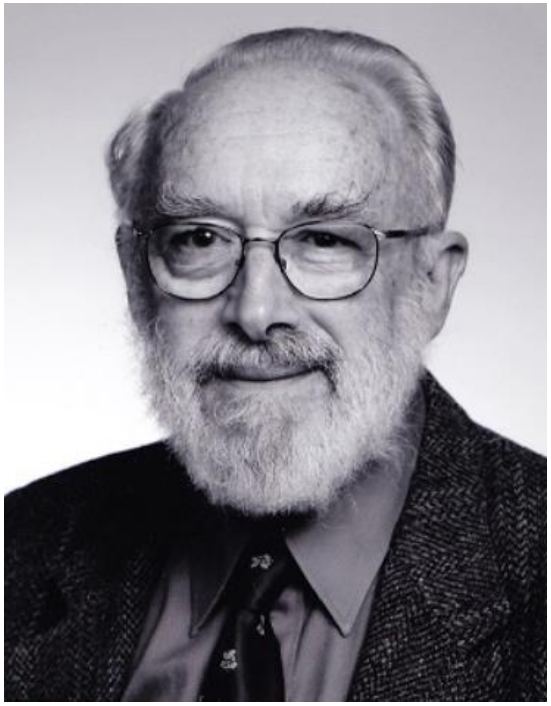
$$F(p_0, p_1) = \sum_b \sqrt{p_0(b)}\sqrt{p_1(b)}$$

The Birth of *QBism*

from *Quantum Bayesianism*

The Coherentist Paradigm

"The topic studied is the situation of an individual who is faced with uncertainty about some events of concern to him. All of us find ourselves in this position … De Finetti's task is first to recognize openly the uncertainty surrounding us and then see how we can best understand it. The main result is that uncertainty can only be described satisfactorily in terms of probability."

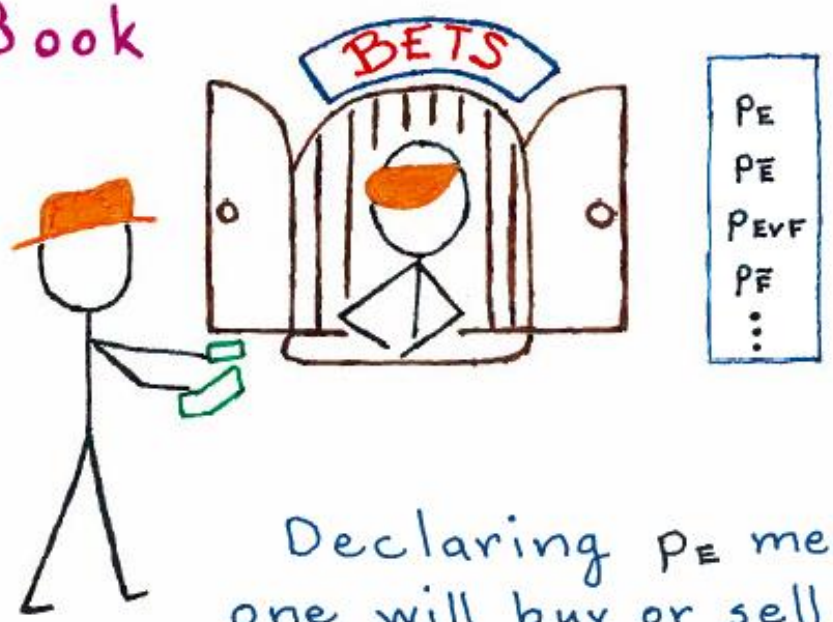


Dennis V. Lindley
1923—2013

"The Bayesian, subjectivist, or coherent, paradigm is egocentric. It is a tale of a [single] person contemplating the world and not wanting to be stupid. He realizes that to do this his statements of uncertainties must [satisfy the laws of probability]."

Defining Probability

Dutch Book



Declaring p_E means one will buy or sell a lottery ticket

Worth \$1 if E

for $\$p_E$.

Dutch Book

Normative Rule:

Never declare p_E, $p_{\bar{E}}$, $p_{E \vee F}$, etc. that will lead to sure loss.

That one simple rule (or suggestion really) leads to all the laws of probability theory.

$$p_{E \vee F} = p_E + p_F \qquad p_{E \wedge F} = p_F p_{E|F}$$

Etc.

Certainty

What means probability 1?

It means one will buy or sell a lottery ticket

Worth #1 if E

for in fact #1, full stop.

That is all it means.

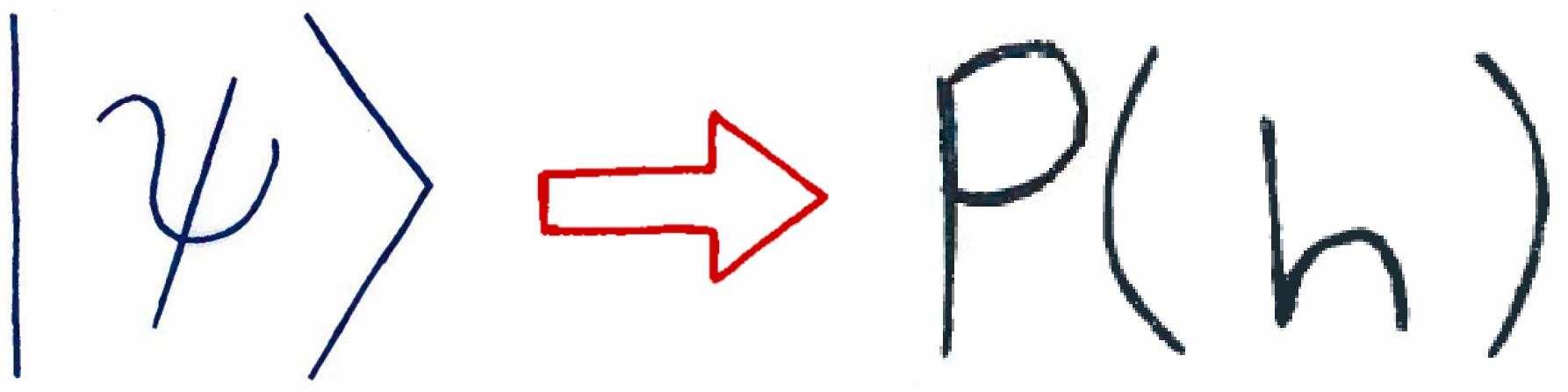
Probability 1 does not imply truth or existence.

"The Bayesian framework replaces … affirmation and denial … by a continuum of judgmental probabilities in the interval 0 to 1, endpoints included – or what comes to the same thing – a continuum of judgmental odds in the interval 0 to ∞, endpoints included. Zero and 1 are probabilities no less than 1/2 and 99/100 are. Probability 1 corresponds to infinite odds, 1:0. That's a reason for thinking in terms of odds: to remember how momentous it may be to assign probability 1 to a hypothesis. It means you'd stake your all on it."

Richard Jeffrey
1926—2002

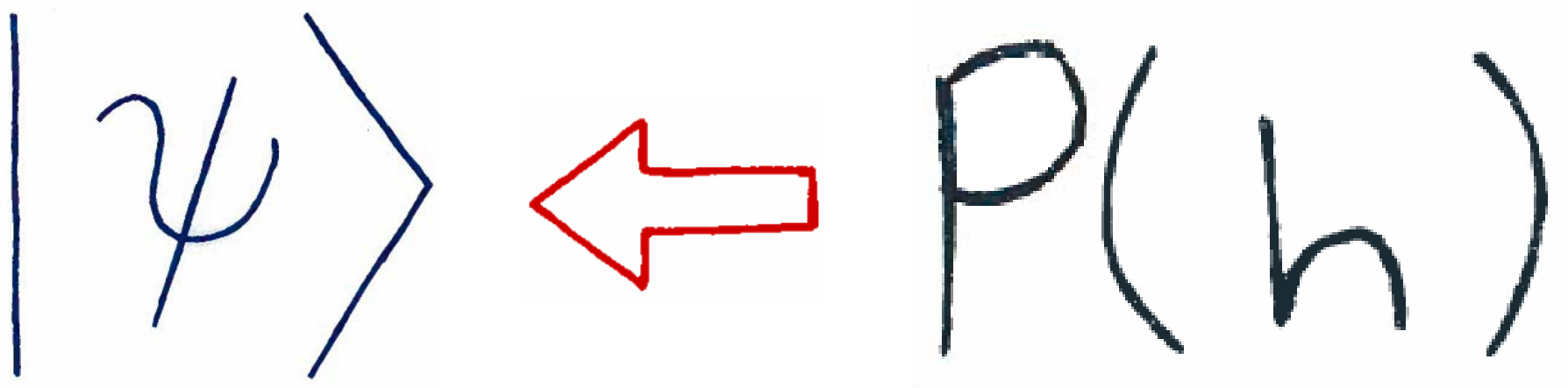
(But that doesn't mean it is true!)

What We Do with Quantum States



We calculate probabilities.

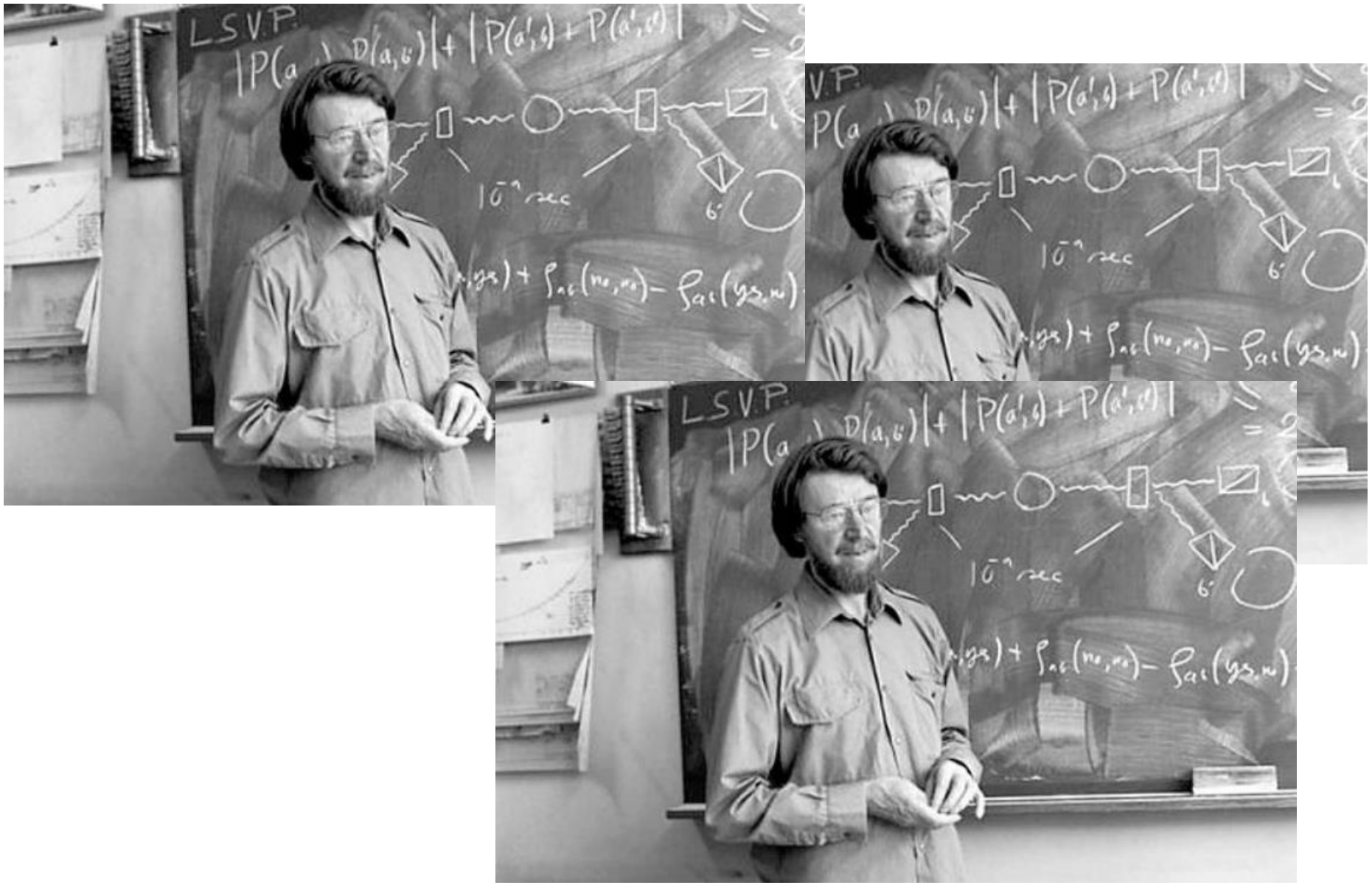
And if you know enough quantum information theory …



… by considering a robust enough set of measurements.

Tenet 1.0: All probabilities, including all quantum probabilities, are so personal or subjective they never tell nature what to do. This includes probability-1 assignments. Quantum states thus have no "ontic hold" on the world.

What was the great lesson of John Bell?

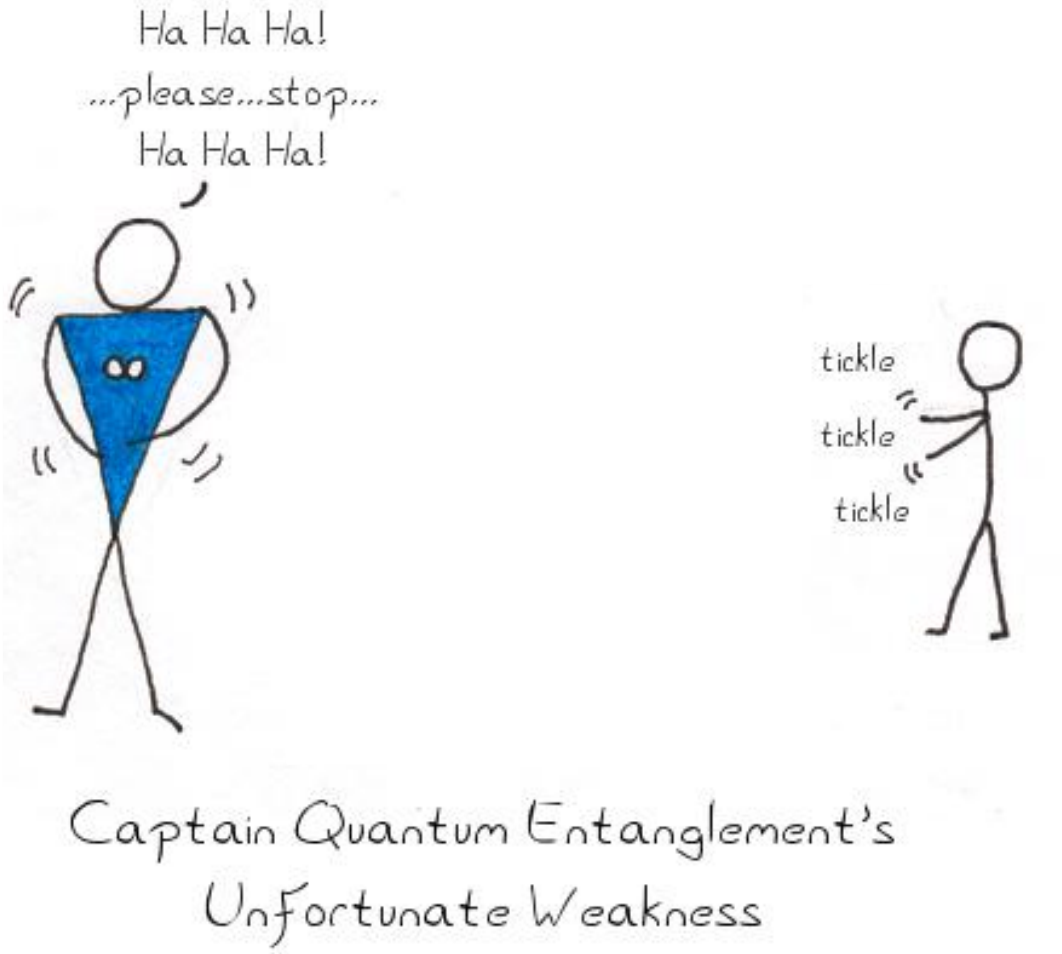


The Culture of Many Philosophy of Physics Meetings

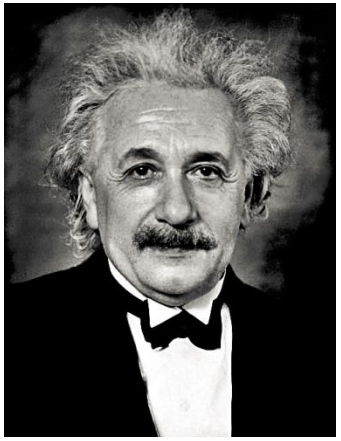
"What Bell proved, and what theoretical physics has not yet properly absorbed, is that the physical world itself is nonlocal."

– Tim Maudlin
"What Bell Did," 2014

But, makes most physicists suspicious. Where does it stop?



Einstein, Podolsky, and Rosen (EPR) Criterion of REALITY



(1935)

"If, without in any way disturbing a system [one can gather the information required to] predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity."

"If I could make one change to the EPR paper in retrospect it would be to alter the characterization of this criterion. The authors call it 'reasonable' and 'in agreement with classical as well as quantum-mechanical ideas of reality', but its status is actually much stronger than that: the criterion is, in the parlance of philosophers, *analytic*. That is, this criterion follows just from the very meanings of the words used in it."

Tim Maudlin

Not in QBism.

"If I could make one change to the EPR paper in retrospect it would be to alter the characterization of this criterion. The authors call it 'reasonable' and 'in agreement with classical as well as quantum-mechanical ideas of reality', but its status is actually much stronger than that: the criterion is, in the parlance of philosophers, *analytic*. That is, this criterion follows just from the very meanings of the words used in it."

Tim Maudlin

And that gets rid of tickle, tickle, tickle …

CAF, Mermin, Schack, Am. J. Phys. **82**, 749 (2014)

The Great Lesson of John Bell for QBism

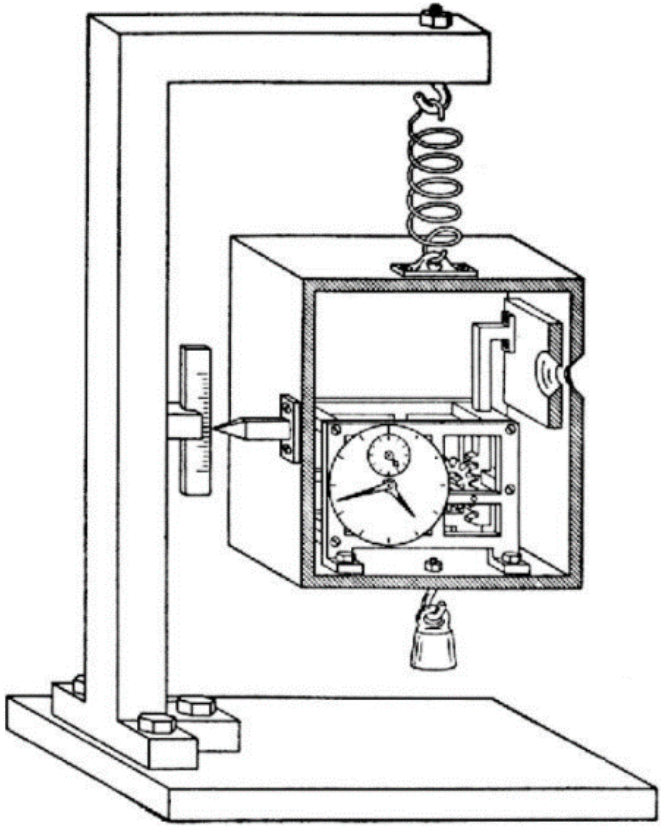
It is not that nature is nonlocal.

It is that nature is creative.

With every quantum measurement set by an experimenter's free will, the world is shaped just a little as it takes part in a moment of creation. So too it is with every action of every agent everywhere, not just experimentalists in laboratories. Quantum measurement represents those moments of creation that are sought out or noticed.

CAF, arXiv:1405.2390

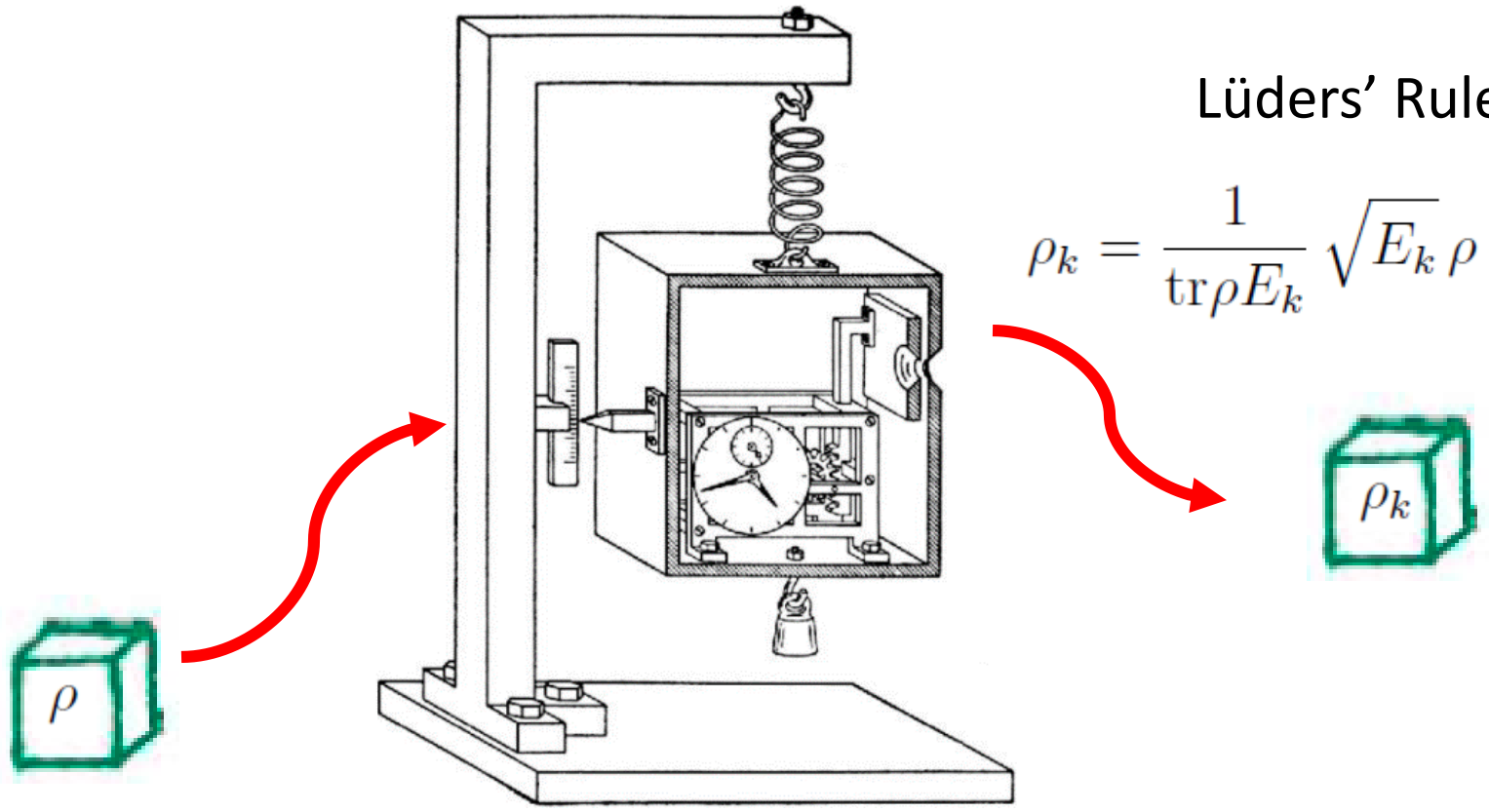
But how much of the infrastructure surrounding quantum states must also be subjective, else inconsistency?



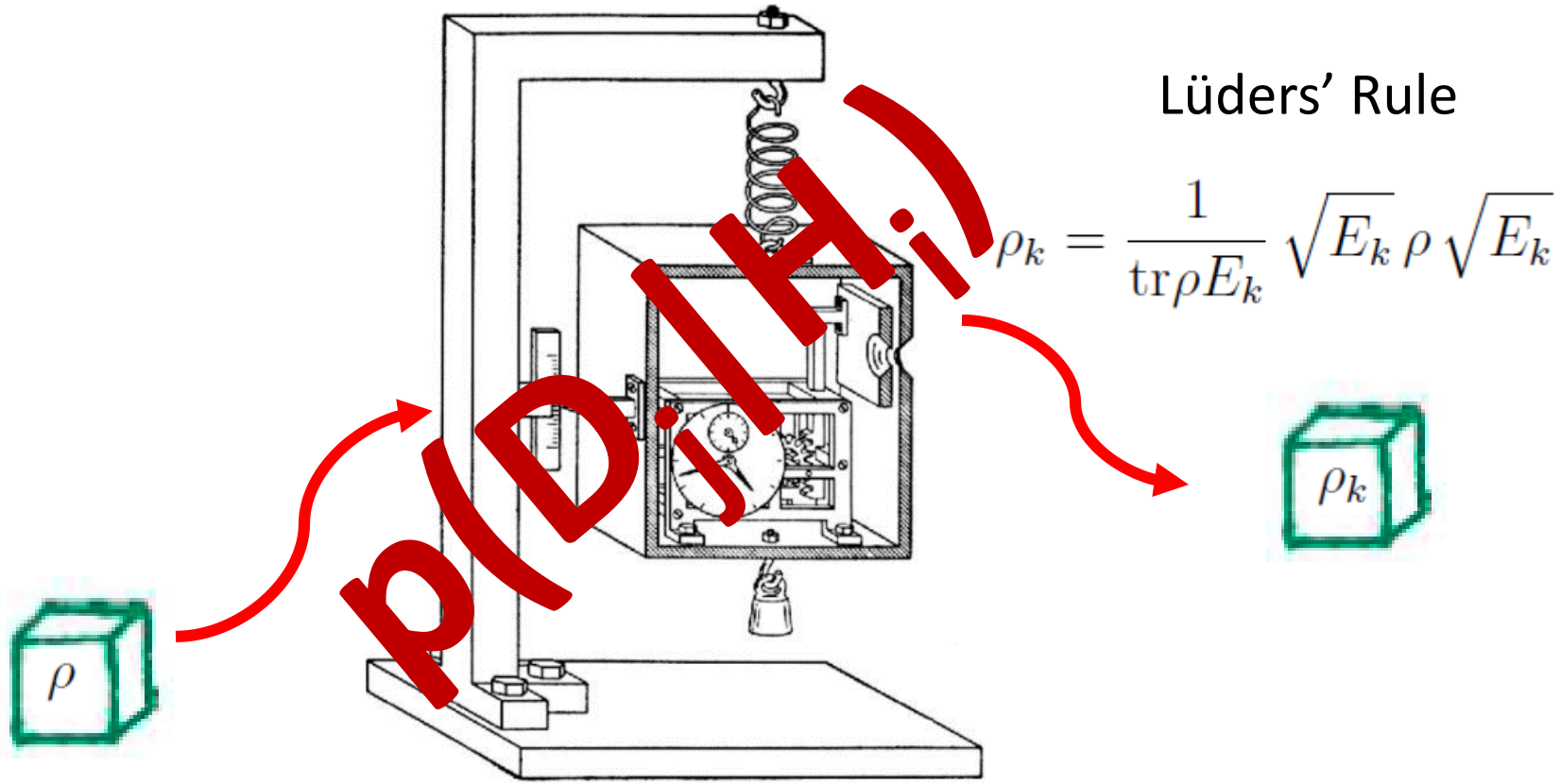
Well, aren’t quantum measurement devices at least objective?

Lüders' Rule

$$\rho_k = \frac{1}{\mathrm{tr}\rho E_k} \sqrt{E_k}\,\rho\,\sqrt{E_k}$$



Well, aren't quantum measurement devices at least objective?



No, they too are of the character of subjective probabilities.

Further we can apply nearly all of our favorite arguments for the subjectivity of quantum states to unitary time evolutions too.

CAF, quant-ph/0205039

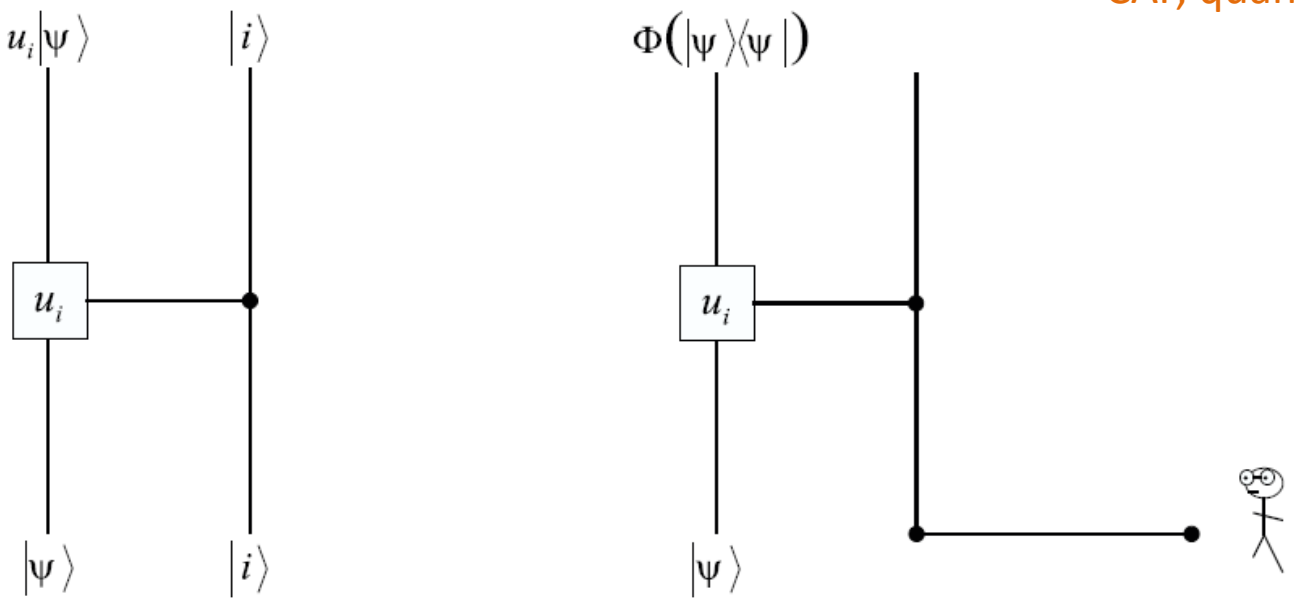
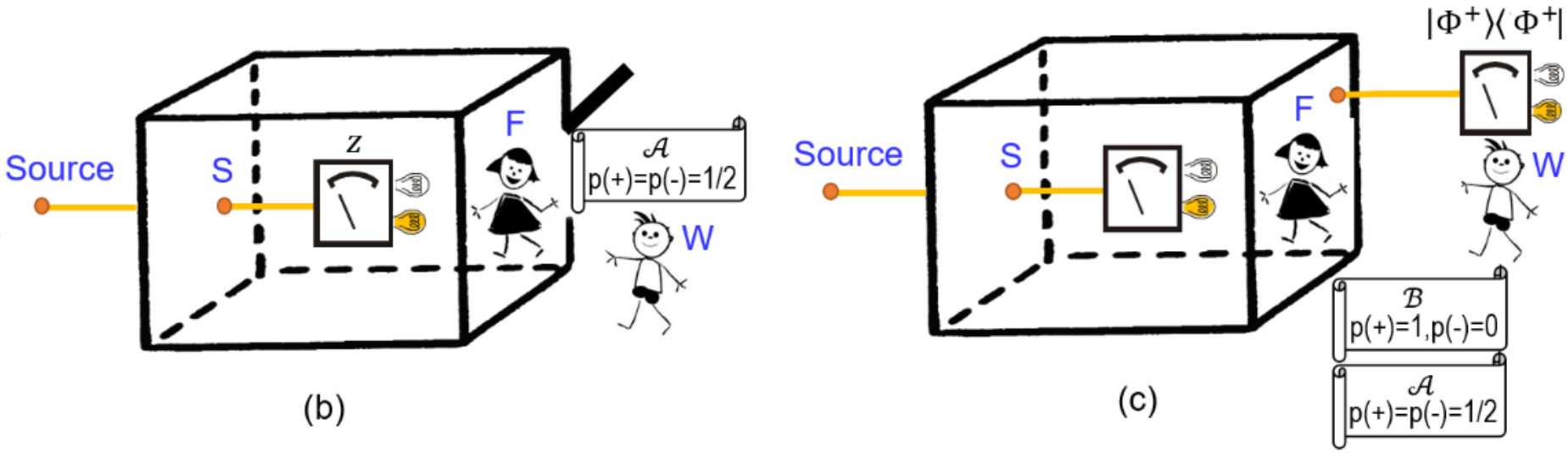


Figure 3: One can use a slight modification of Einstein's argument for the subjectivity of the quantum state to draw the same conclusion for quantum time evolutions. By performing measurements on a far away system, one will ascribe one or another completely positive map to the evolution of the left-most qubit. Therefore, accepting physical locality, the time evolution map so ascribed cannot be a property intrinsic to the system.

Tenet 1.1: All probabilities, including all quantum probabilities, are so personal or subjective they never tell nature what to do. This includes probability-1 assignments. Quantum states, measurement operators, and unitary evolutions thus have no "ontic hold" on the world.

Topical Application:

Baumann & Brukner, “Wigner’s friend as a rational agent,’’ arXiv:1901.11274.

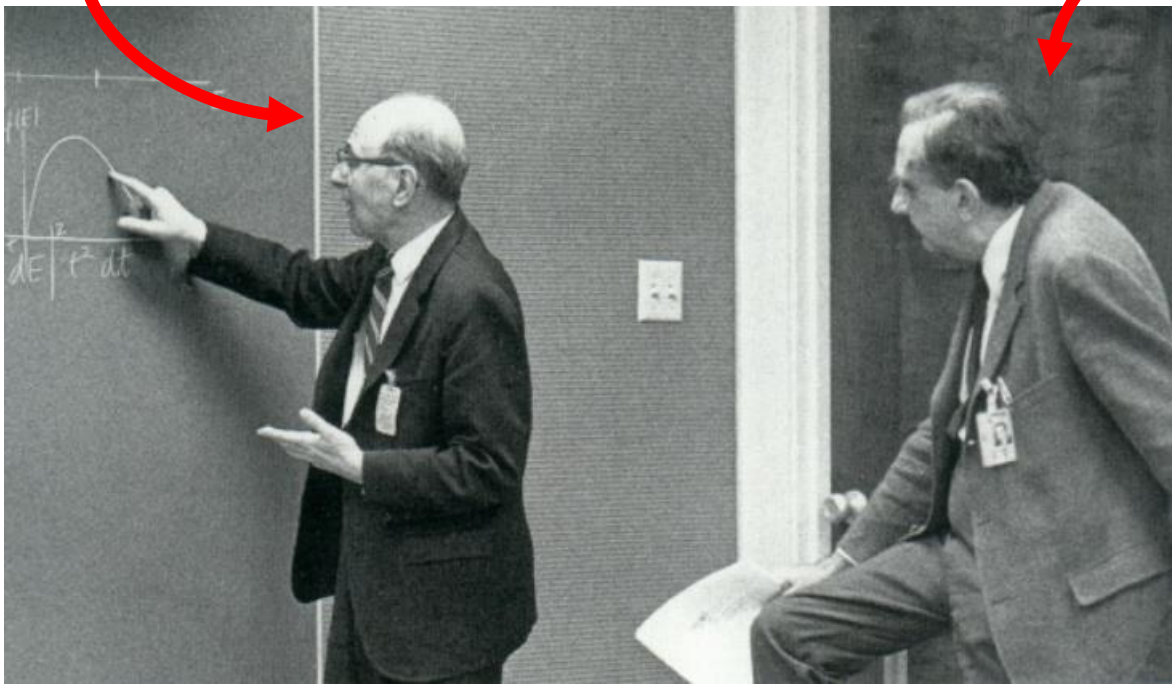


(See Rüdiger Schack’s talk.)

But what does Wigner's friend bring to QBism?

Wigner

His Friend



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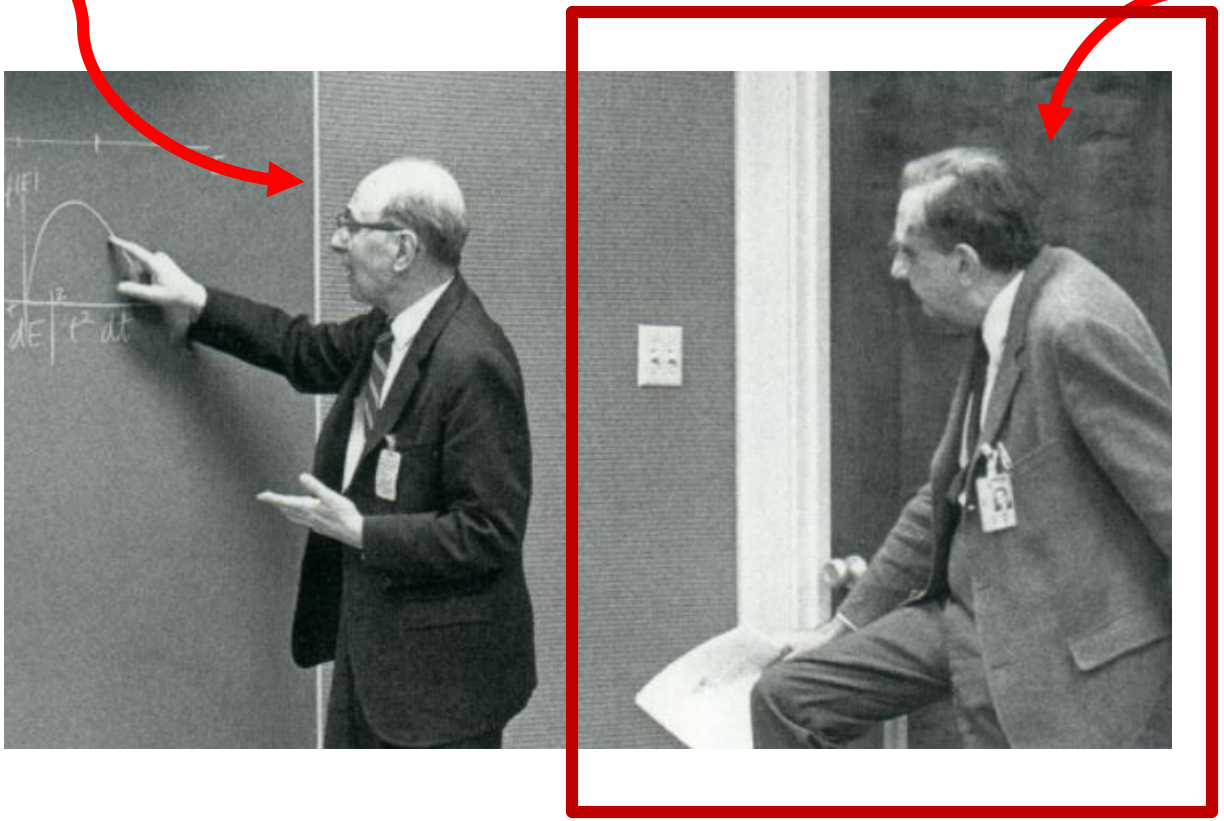


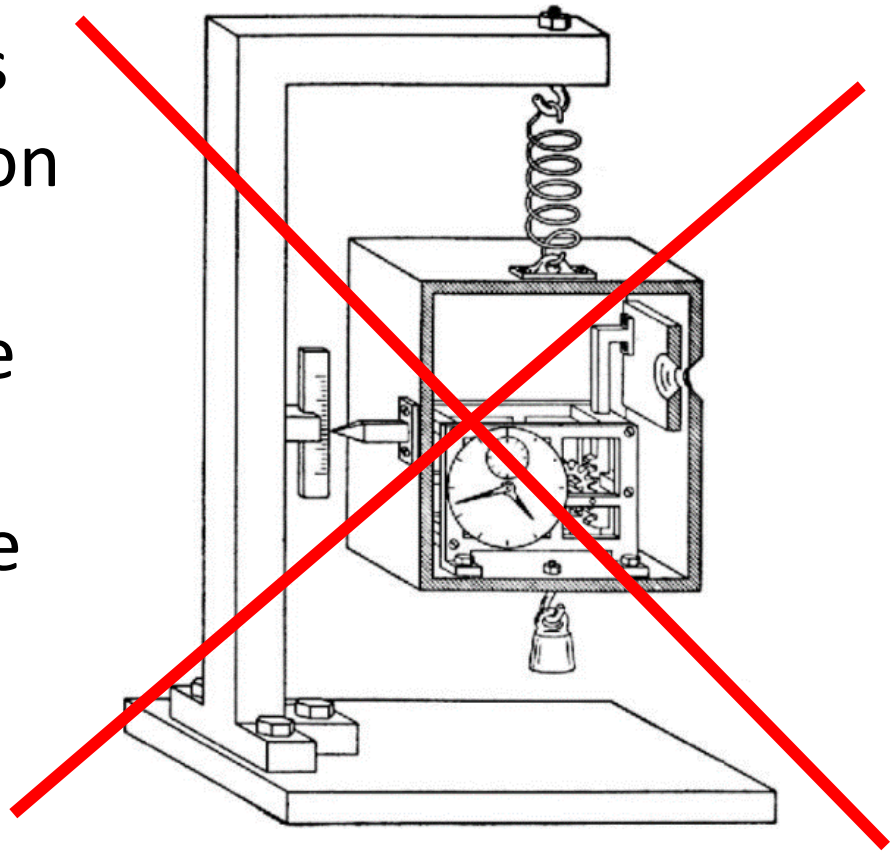
Facts for the Agent

C. M. Caves, CAF, R. Schack, "Subjective Probability and Quantum Certainty," SHPMP **38**, 255 (2007).

Referee: You write, "The occurrence or nonoccurrence of an event is a ***fact for the agent***." What work, precisely, is the modifier 'for the agent' supposed to be doing here? It comes across as slightly odd to say that the occurrence is a fact 'for the agent' … (Of course, there is no inconsistency here: apparently, facts are ***facts for everybody*** on your view, …. But still the way you put things here strikes me as misleading somehow.)

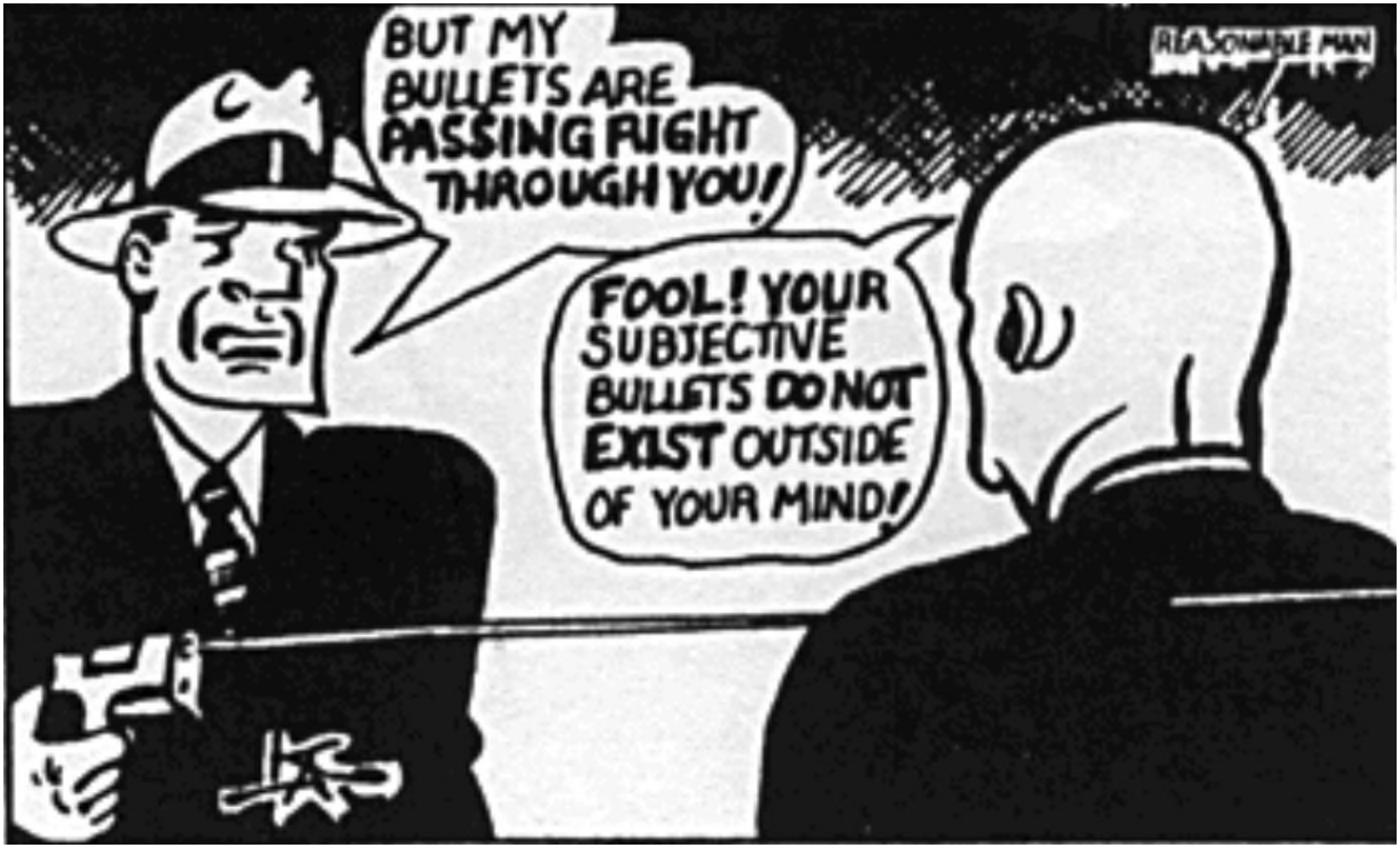
Authors: This paper does not emphasize it, but no, we **do not mean** "the facts we are talking about here are ***facts for everybody***." We mean that the facts too are personal …. A better exposition would have emphasized the full setting of our view … We do not … [give] the data obtained in a quantum measurement an autonomous existence—for instance, as something beyond the agent's sensations. That would run into inconsistencies in a "Wigner's friend" scenario. Nonetheless, quantum measurement outcomes are beyond the control of the agent—they are only born in the interaction—and thus are not functions of the agent in the way that his degrees of belief are.

Tenet 2: A quantum measurement is any action an agent takes upon the world, and its outcome *just is* the consequent personal experience this induces in the agent. Particularly, quantum measurement outcomes are *not*, to paraphrase Bohr, instances of "irreversible amplification objectively recorded for everyone to see in a device whose design is communicable in common language suitably refined by the terminology of classical physics."



Topical Application: Frauchiger & Renner No-Go Theorem

(See Rüdiger Schack's talk.)


BUT MY BULLETS ARE PASSING RIGHT THROUGH YOU!
REASONABLE MAN
FOOL! YOUR SUBJECTIVE BULLETS DO NOT EXIST OUTSIDE OF YOUR MIND!

A Corrective to Jaynes

Some (most!) elements of the formalism are *subjective*
—more subjective than you've ever seen*!*

Whereas some relations in the formalism are *objective*
—as objective as one could want of a physical theory.

A Corrective to Jaynes

Some (most!) elements of the formalism are *subjective*
—more subjective than you've ever seen*!*

Whereas some relations in the formalism are *objective*
—as objective as one could want of a physical theory.

Tenet 3: The Born Rule—the foundation of what quantum theory means for QBism—is a normative statement. It is about the decision-making behavior *any* individual agent should strive for; it is not a descriptive "law of nature" in the usual sense.

Not like

$$\vec{F} = m\vec{a}$$

Not like

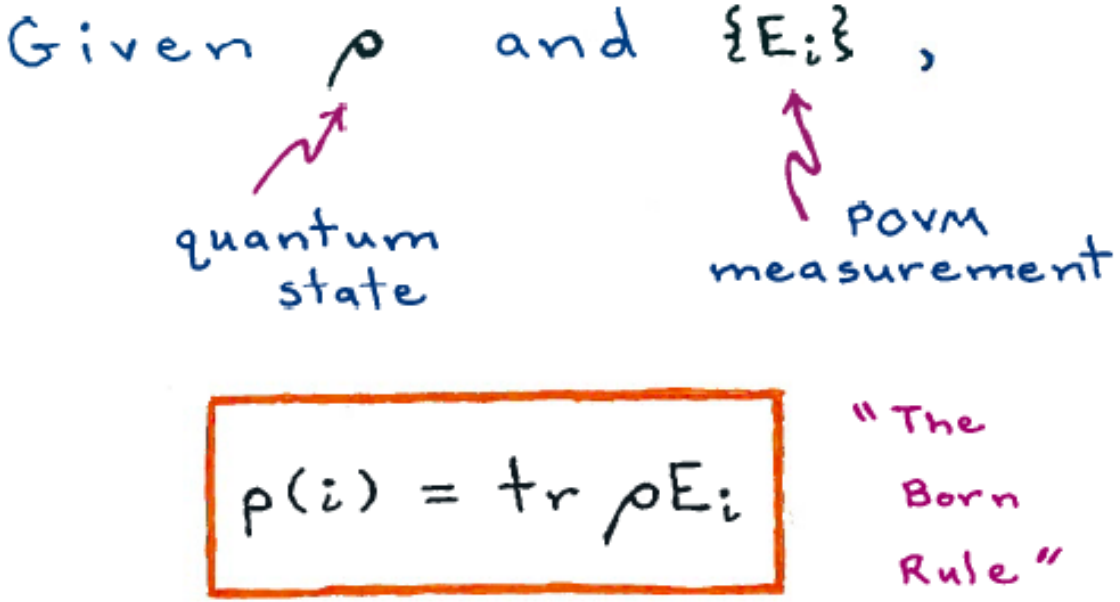
$$\vec{\nabla}\cdot\vec{E} = \frac{1}{\epsilon_0}\rho \qquad \vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

$$\vec{\nabla}\times\vec{B} = \mu_0\vec{J} + \mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t} \qquad \vec{\nabla}\cdot\vec{B} = 0$$

Not like

$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$

The Born Rule



How does one even start to view this as a normative statement?

E. T. Jaynes, 2

"Of course, the QM formalism also contains fundamentally important and correct ontological elements … It seems that, to unscramble the epistemological probability statements from the ontological elements we need to find a different formalism, isomorphic in some sense but based on different variables; it was only through some weird mathematical accident that it was possible to find a variable ψ which scrambles them up in the present way."

Standard Measurements	Generalized Measurements
$\{\Pi_i\}$	$\{E_b\}$
$\langle\psi\|\Pi_i\|\psi\rangle \geq 0, \forall\|\psi\rangle$	$\langle\psi\|E_b\|\psi\rangle \geq 0, \forall\|\psi\rangle$
$\sum_i \Pi_i = I$	$\sum_b E_b = I$
$p(i) = \mathrm{tr}\,\rho\Pi_i$	$p(b) = \mathrm{tr}\,\rho E_b$
$\Pi_i \Pi_j = \delta_{ij}\Pi_i$	—

John von Neumann

Alexander Holevo

A Very Fundamental Mmt ?

Suppose d^2 projectors $\Pi_i = |\psi_i\rangle\langle\psi_i|$ satisfying

$$\mathrm{tr}\,\Pi_i \Pi_j = \frac{1}{d+1} \quad , \quad i \neq j$$

exist. ← called SIC.

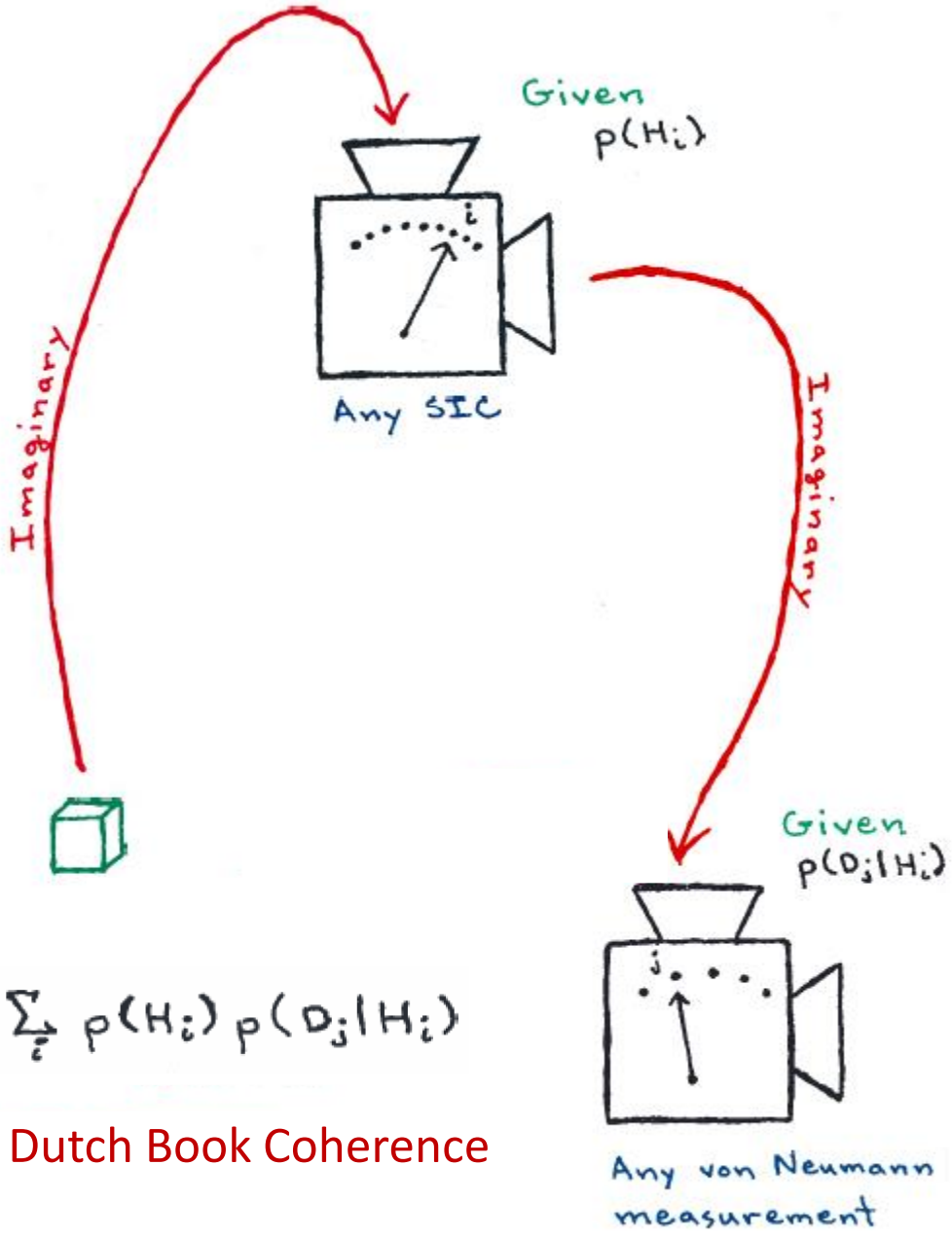
Can prove:

1) the Π_i linearly independent

2) $\sum_i \frac{1}{d} \Pi_i = I$

Fulfills the conditions for an

"informationally complete" measurement.

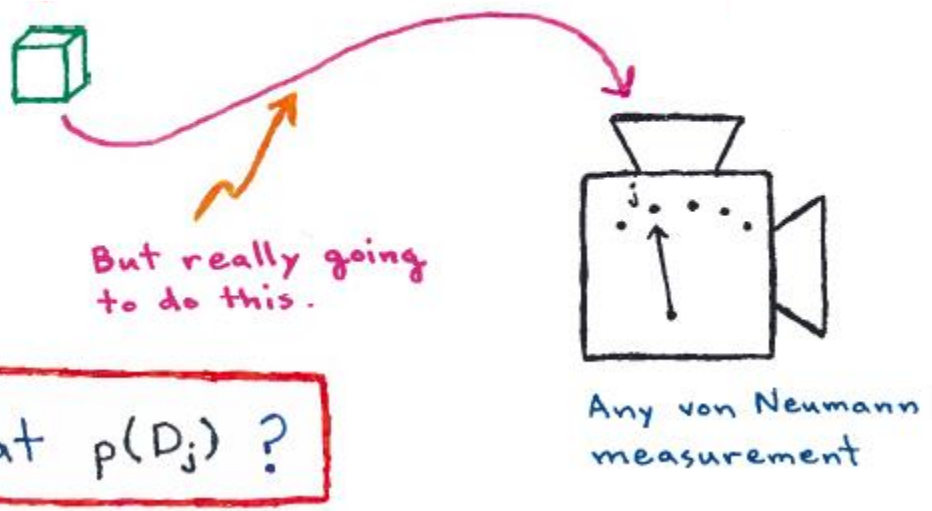


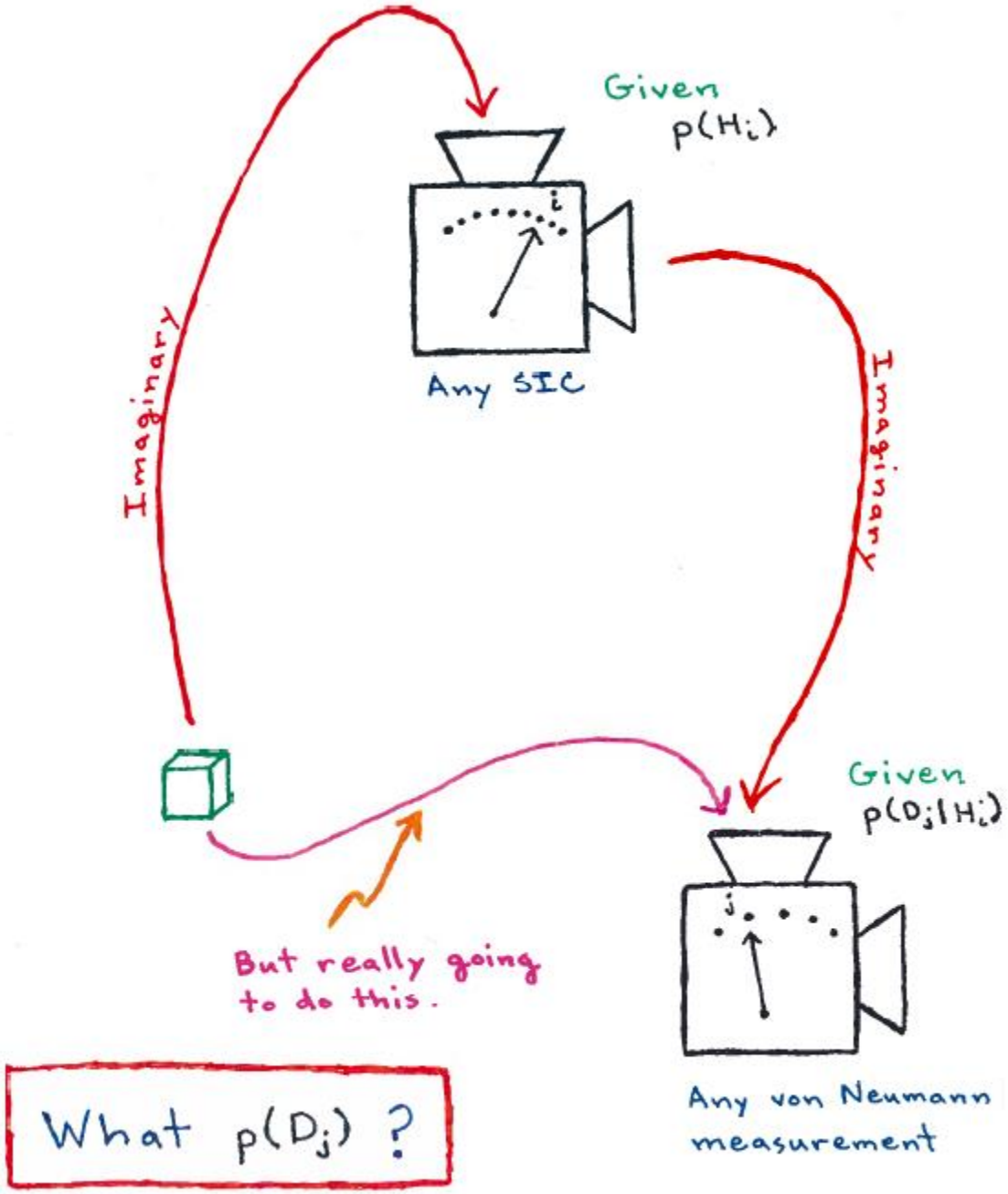
$$p(D_j) = \sum_i p(H_i)\, p(D_j|H_i)$$

Demanded by Dutch Book Coherence

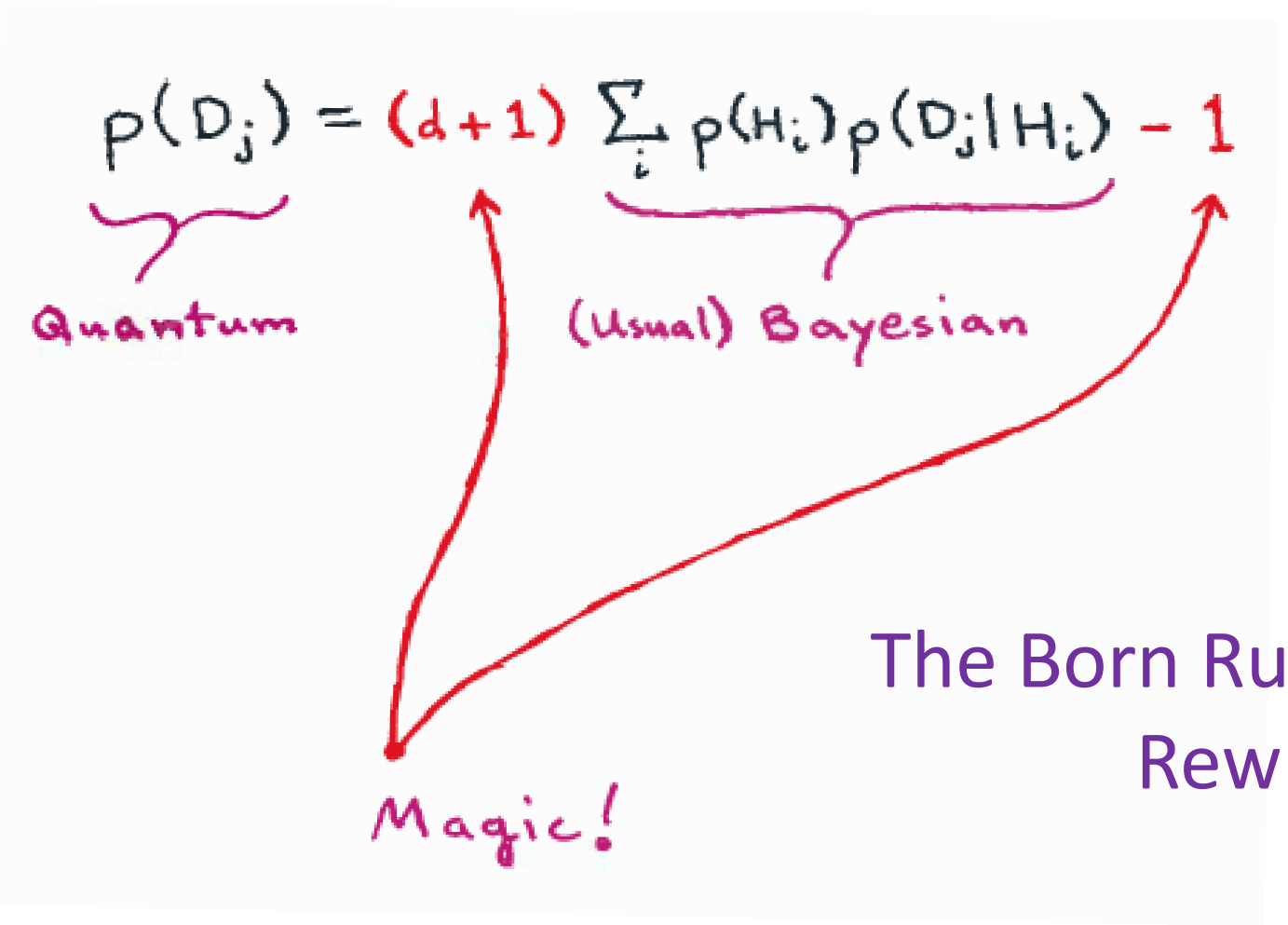

But really going to do this.
j
Any von Neumann measurement
What $p(D_j)$?

Born rule, of course.




Given
$p(H_i)$
Any SIC
Imaginary
Imaginary
Given
$p(D_j|H_i)$
But really going to do this.
Any von Neumann measurement
What $p(D_j)$?

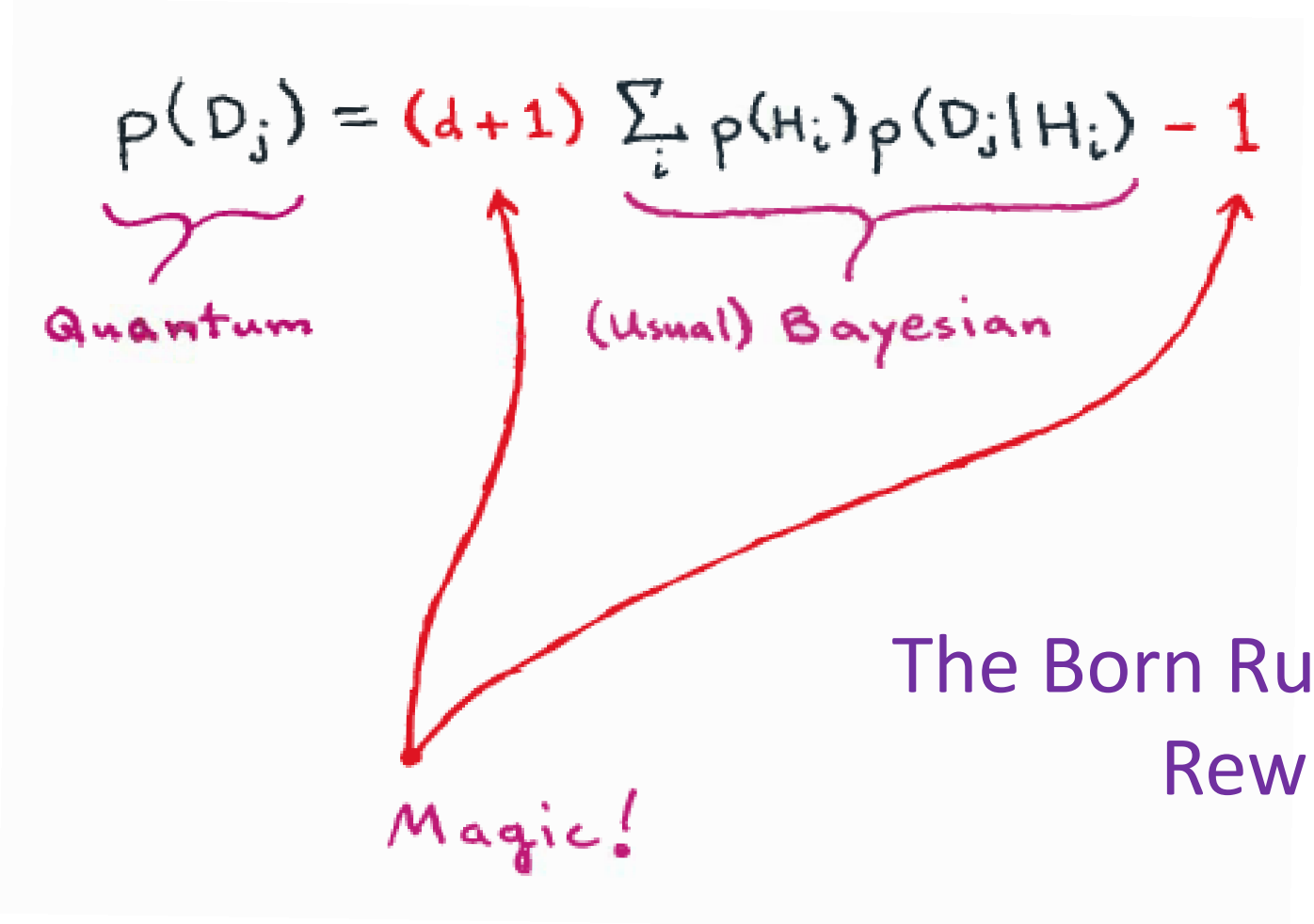
For QBism, the Born Rule Is an Addition to Dutch Book Coherence



The Born Rule Rewritten

CAF, Schack, Rev. Mod. Phys. **85**, 1693 (2013)

For QBism, the Born Rule Is an Addition to Dutch Book Coherence



And that suggests a normative reading …

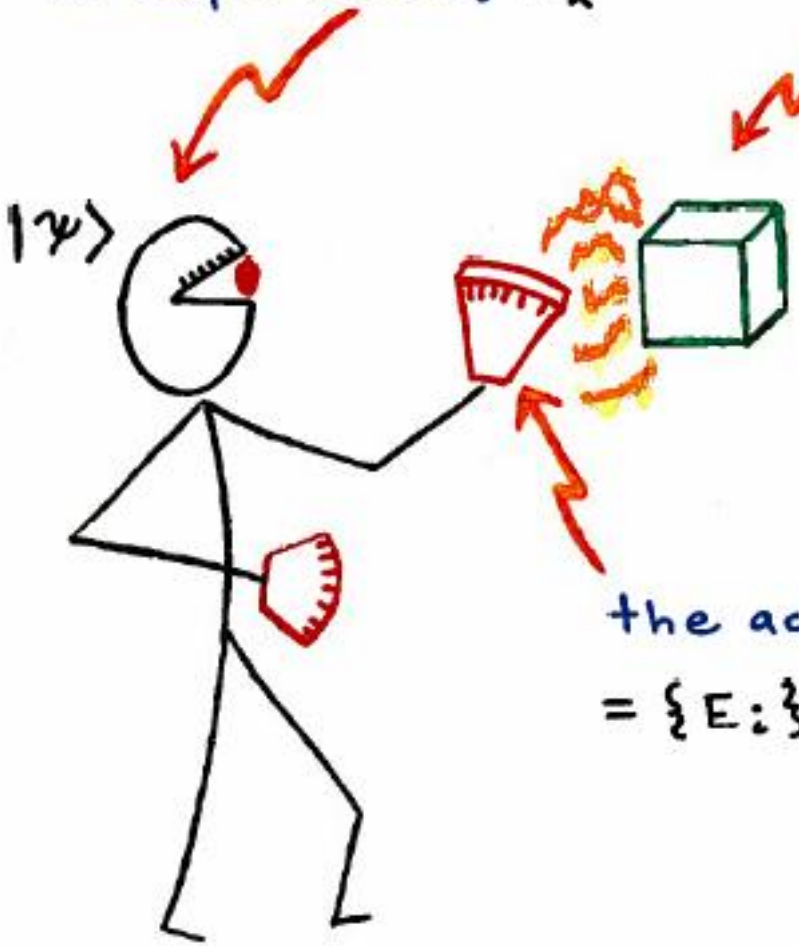
CAF, Schack, Rev. Mod. Phys. **85**, 1693 (2013)

the consequence

= an experience, E_k

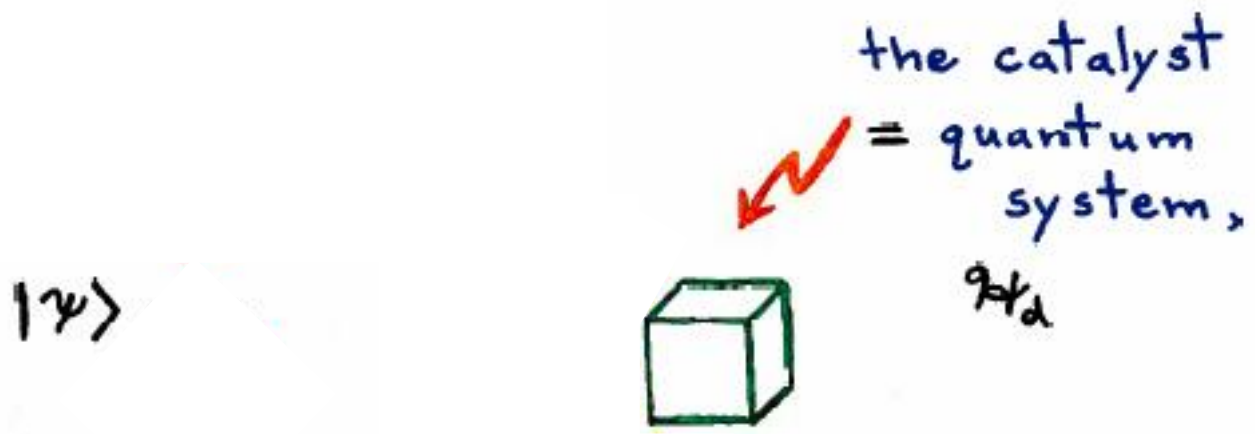
the catalyst

= quantum system, ψ_d

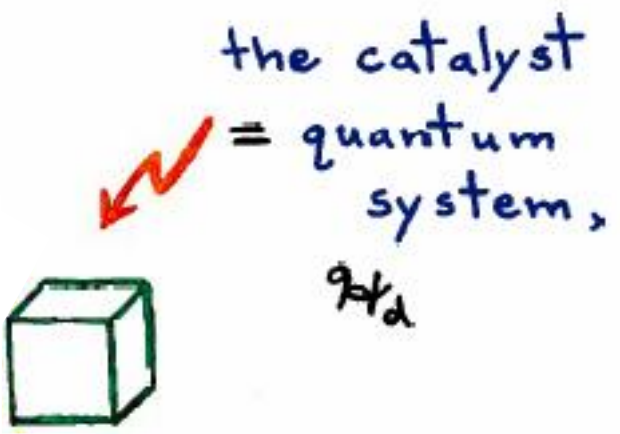


the action

$= \{E_i\}$



What happens if we wipe the agent out of the picture?



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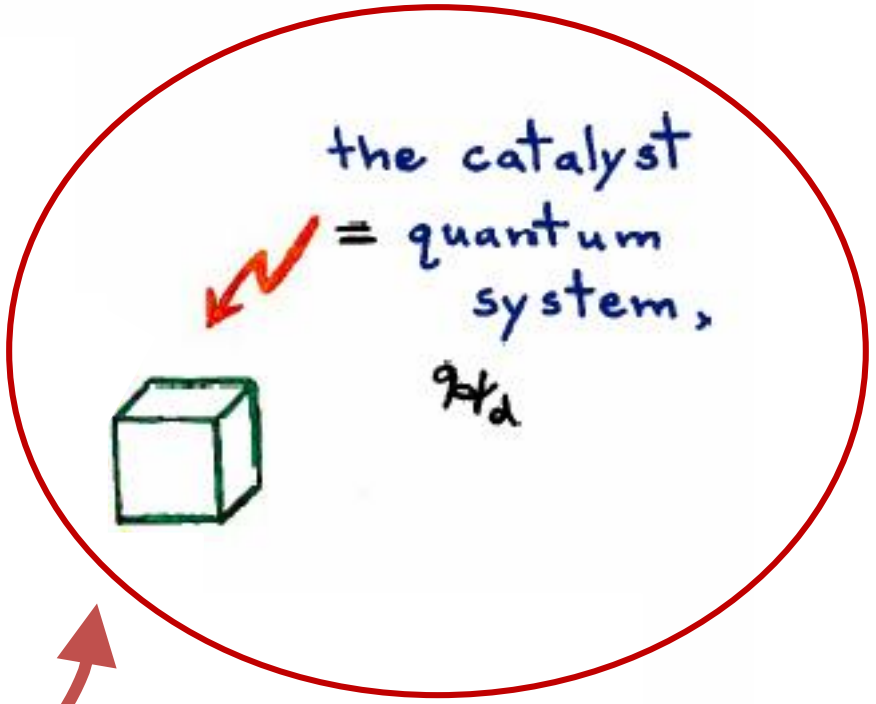
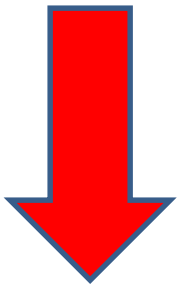


But this didn't
go Poof!

What Else Doesn't Go Poof.

(That's a statement, not a question.)

$$p(D_j) = (d+1) \sum_i p(H_i)\, p(D_j \mid H_i) - 1$$



I.e., the relation as a normative rule stays behind!

Newton and the Law of Universal Gravitation

$$F = G\frac{m_1 m_2}{r^2}$$

Quantum Theory as a Rubric for All That Is

Rubric = “a direction for the conduct of divine service”

Quantum Theory as a Rubric for All That Is

Rubric = "a direction for the conduct of divine service"

Instead:

Quantum Theory as the Expression of
Just One Feature of all Matter

Our only handle on that is the Born Rule:

- Find an expression of the Born Rule *within* quantum theory that makes it clear as a normative addition to probabilistic coherence.

- Throw away the rest of the theory and elevate that expression to be the key axiom of a new framework.

- If a reconstruction of quantum theory can be made to work in this framework, then think hard about why that axiom should have been adopted in the first place.

- The reason why—whatever it be—then becomes the real plot of QBism and its contribution to our understanding of reality.

But

QBism is a project.

Erwin Schrödinger on Responsible Physics*

In an honest search for knowledge you quite often have to abide by ignorance for an indefinite period. Instead of filling a gap by guesswork, genuine science prefers to put up with it; and this, not so much from conscientious scruples about telling lies, as from the consideration that, however irksome the gap may be, its obliteration by a fake removes the urge to seek after a tenable answer. So efficiently may attention be diverted that the answer is missed even when, by good luck, it comes close at hand. The steadfastness in standing up to a *non liquet*, nay in appreciating it as a stimulus and a signpost to further quest, is a natural and indispensable disposition in the mind of a scientist. This in itself is apt to set him at variance with the religious aim of closing the picture, unless each of the two antagonistic attitudes, both legitimate for their respective purposes, is applied with prudence.

— Erwin Schrödinger, 1954

* This message sponsored by *QBists for Quantum Attitude Reform.*