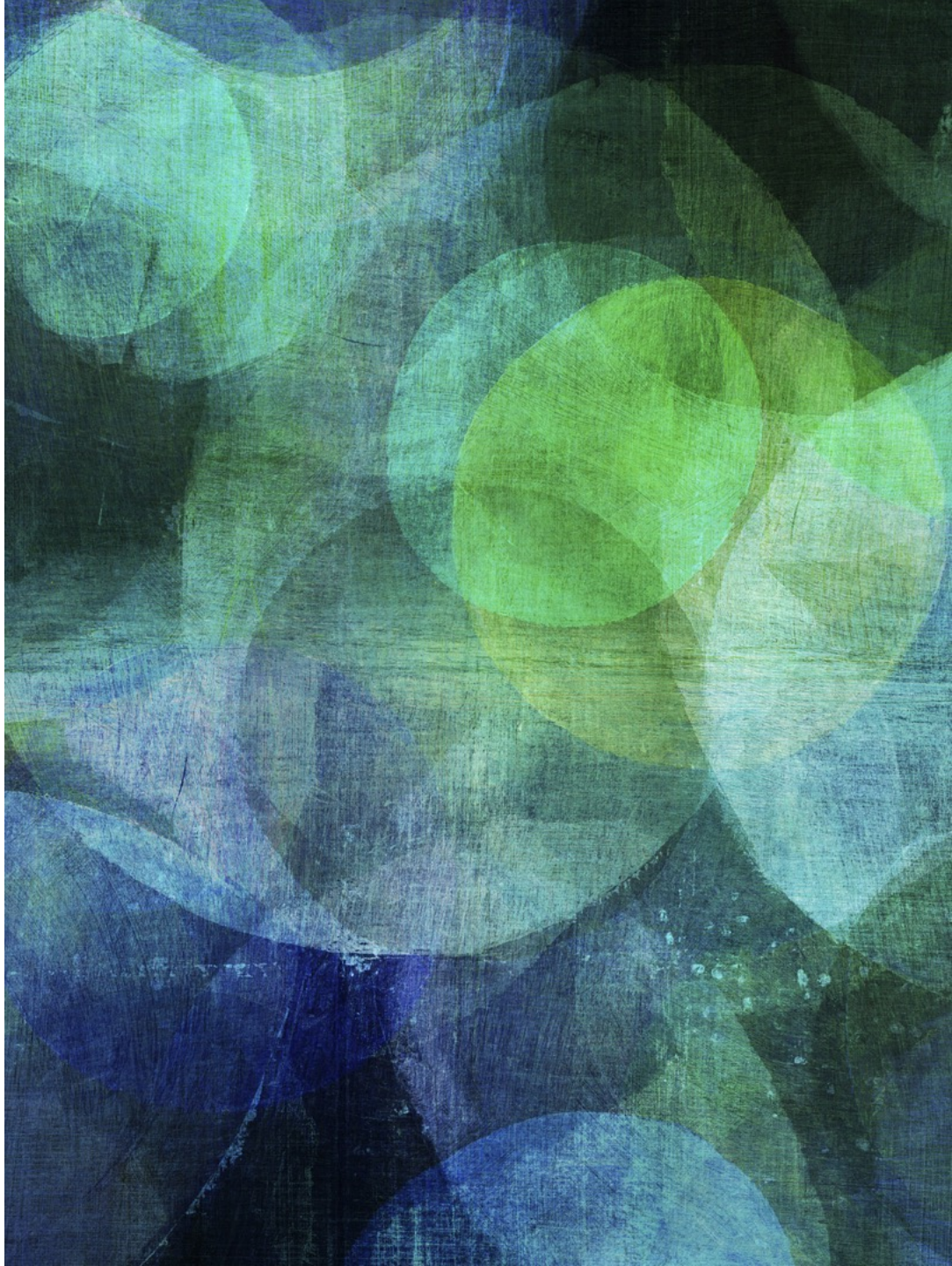
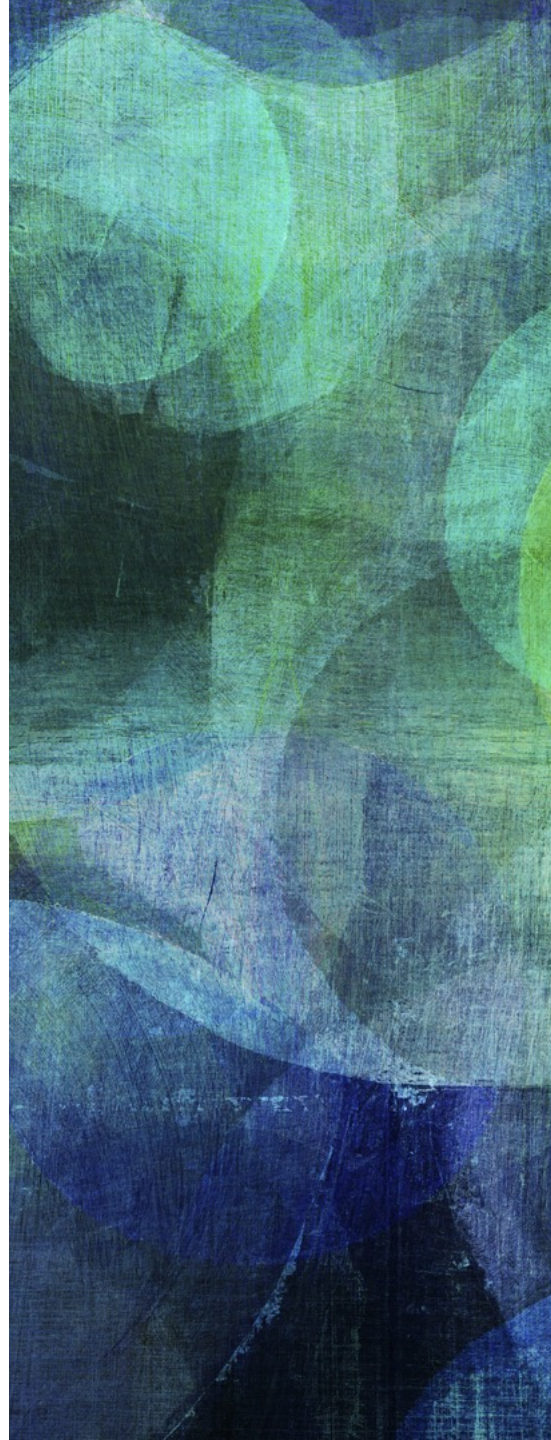
Why Quantum?

Yelena Guryanova
(Institute for Quantum Optics and Quantum Information, Vienna)

Friday 18th November 2022, Trinity College, Dublin.

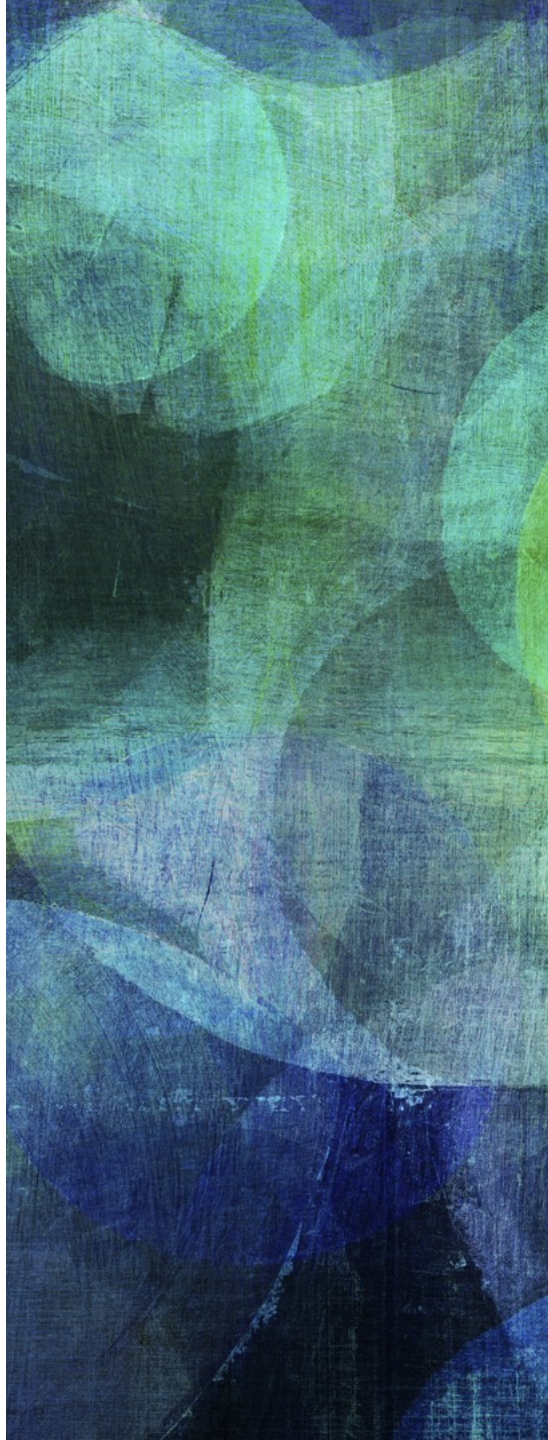


The question in questions



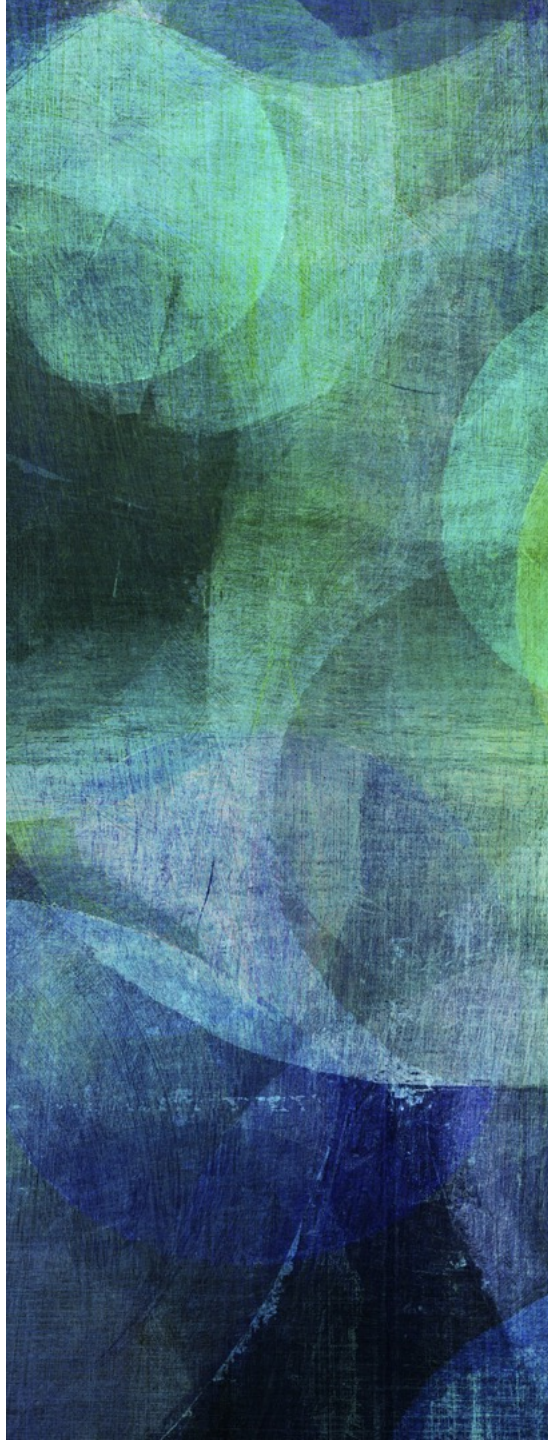
The question in questions

- When we look at the results of experiments in the lab, why is it that they all seem to obey the postulates of quantum mechanics?
- Could there be some underlying principle, (or a set of principles) that singles out quantum theory as an ‘’island in theory space’’?
- Is quantum theory special because it obeys special relativity?
- Could one devise an ‘almost quantum’ theory that satisfies similar requirements?
- Is quantum theory the ‘final’ theory?



Correlations

- ‘Looking’ at experimental outcomes in physics (scattering experiments, time of arrival, voltage record, current detection)
- Emergent statistical patterns = **correlations**
- To compare correlations, it is easier to work in *a device independent formalism* –a framework that makes no assumptions on the devices (experimental apparatus) used to perform the experiments. You don’t need to trust the manufacture of your equipment
- Why correlations ? Because they are the basic object in quantum information theory.



Black box scenario: a basic way to think about experimental results



$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

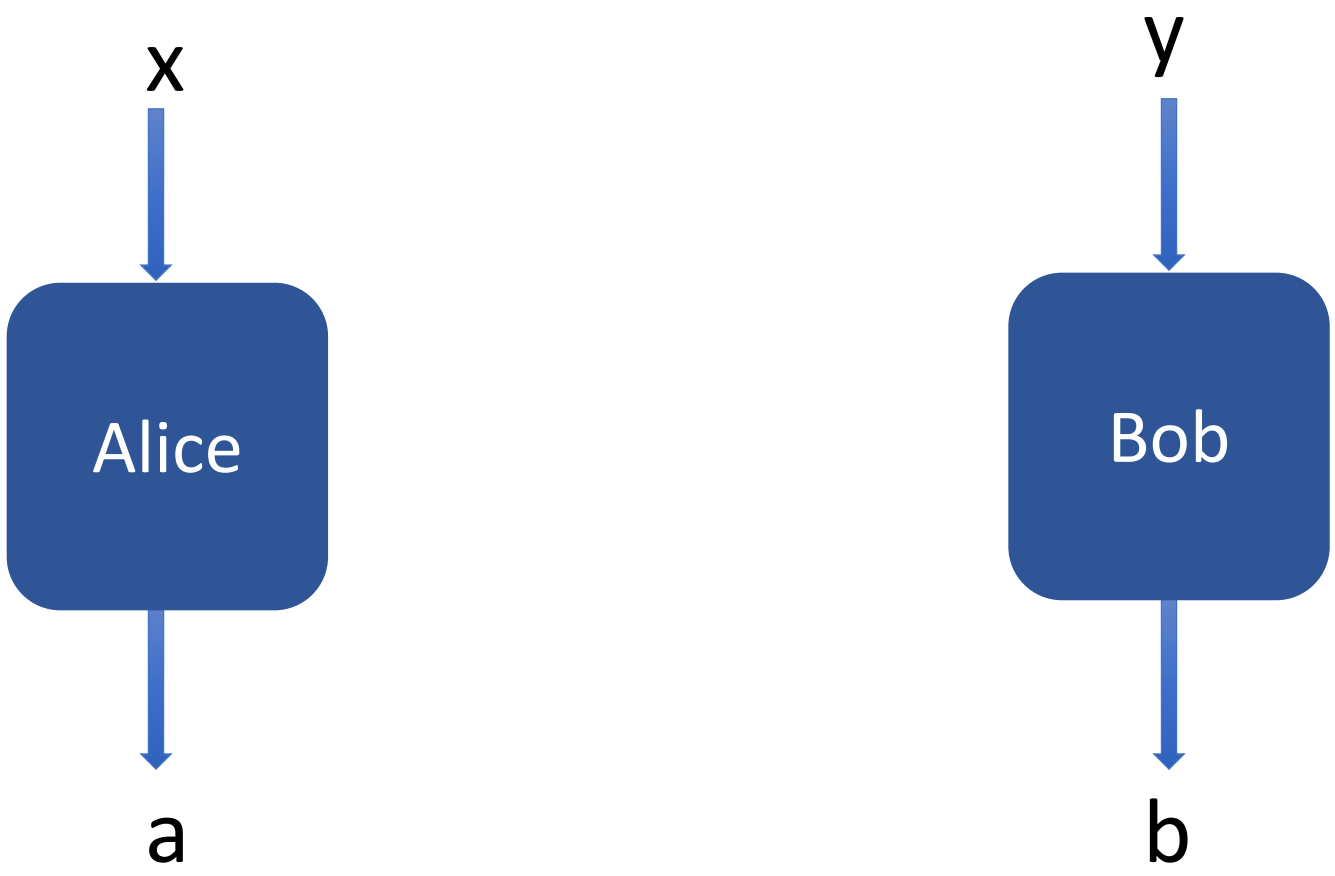
Black box scenario: a basic way to think about experimental results



$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results



$$x, y, a, b \in \{0, 1\}$$

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Black box scenario: a basic way to think about experimental results

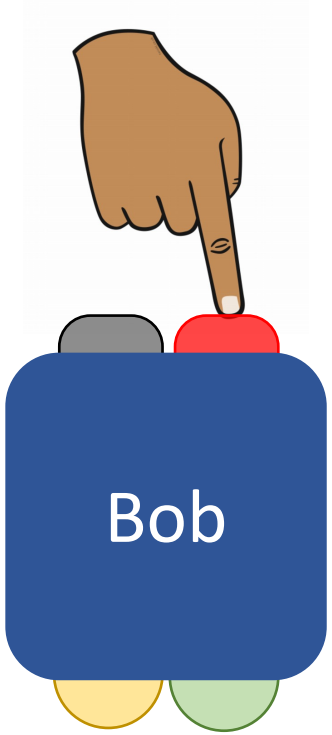


$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results





$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
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Black box scenario: a basic way to think about experimental results



$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

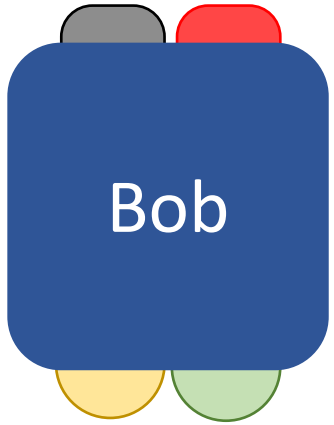
Black box scenario: a basic way to think about experimental results

5. Black
4. Black
3. Red
2. Black
1. Red



1. Yellow
2. Green
3. Green

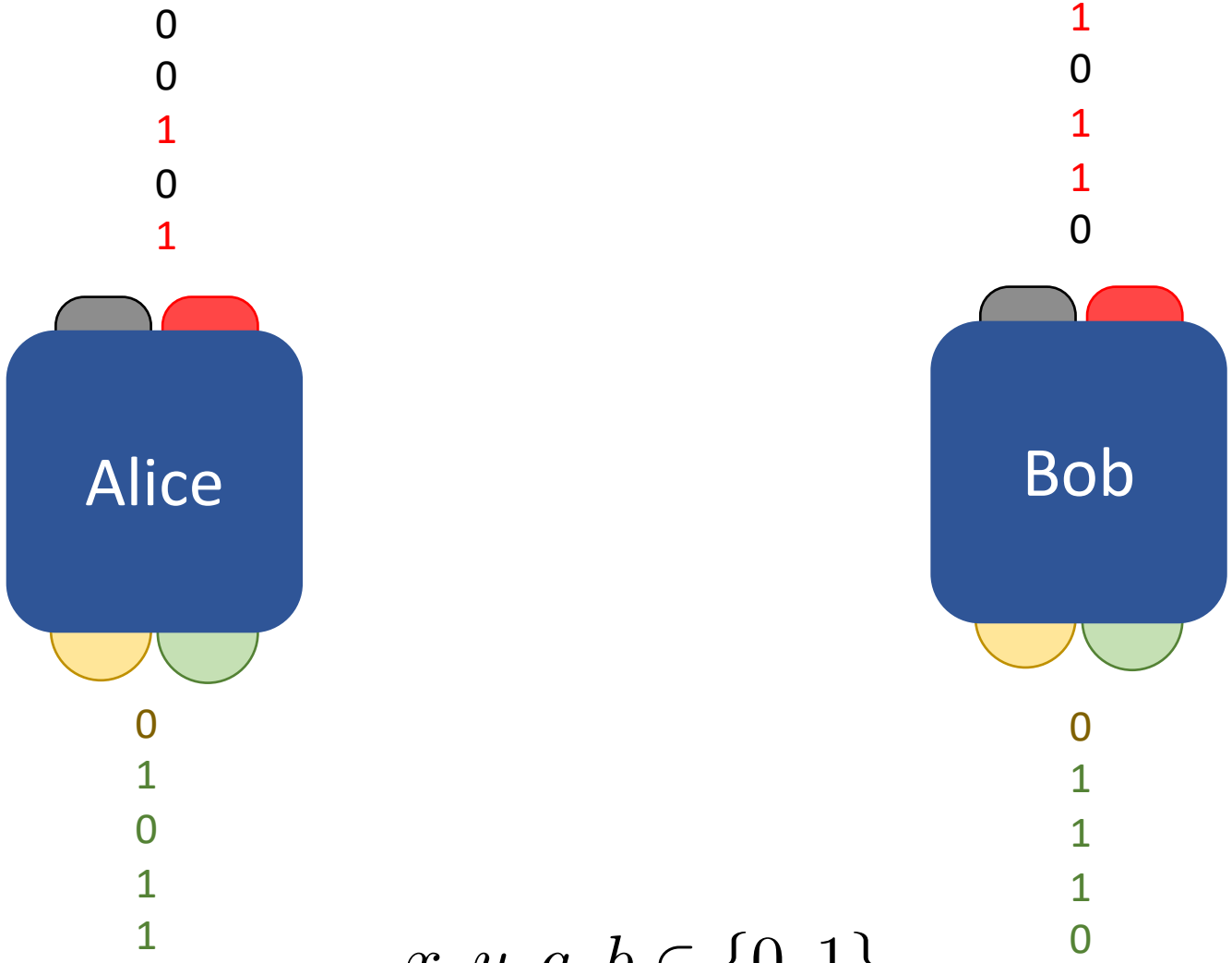
5. Red
4. Black
3. Red
2. Red
1. Black



$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results



$$x, y, a, b \in \{0, 1\}$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results

DIFFERENT INPUTS

Alice	Bob
0	1
0	0
1	1
0	1
1	0



SAME OUTPUTS

Alice	Bob
0	0
1	1
1	1
0	1
0	0

$$x, y, a, b \in \{0, 1\}$$

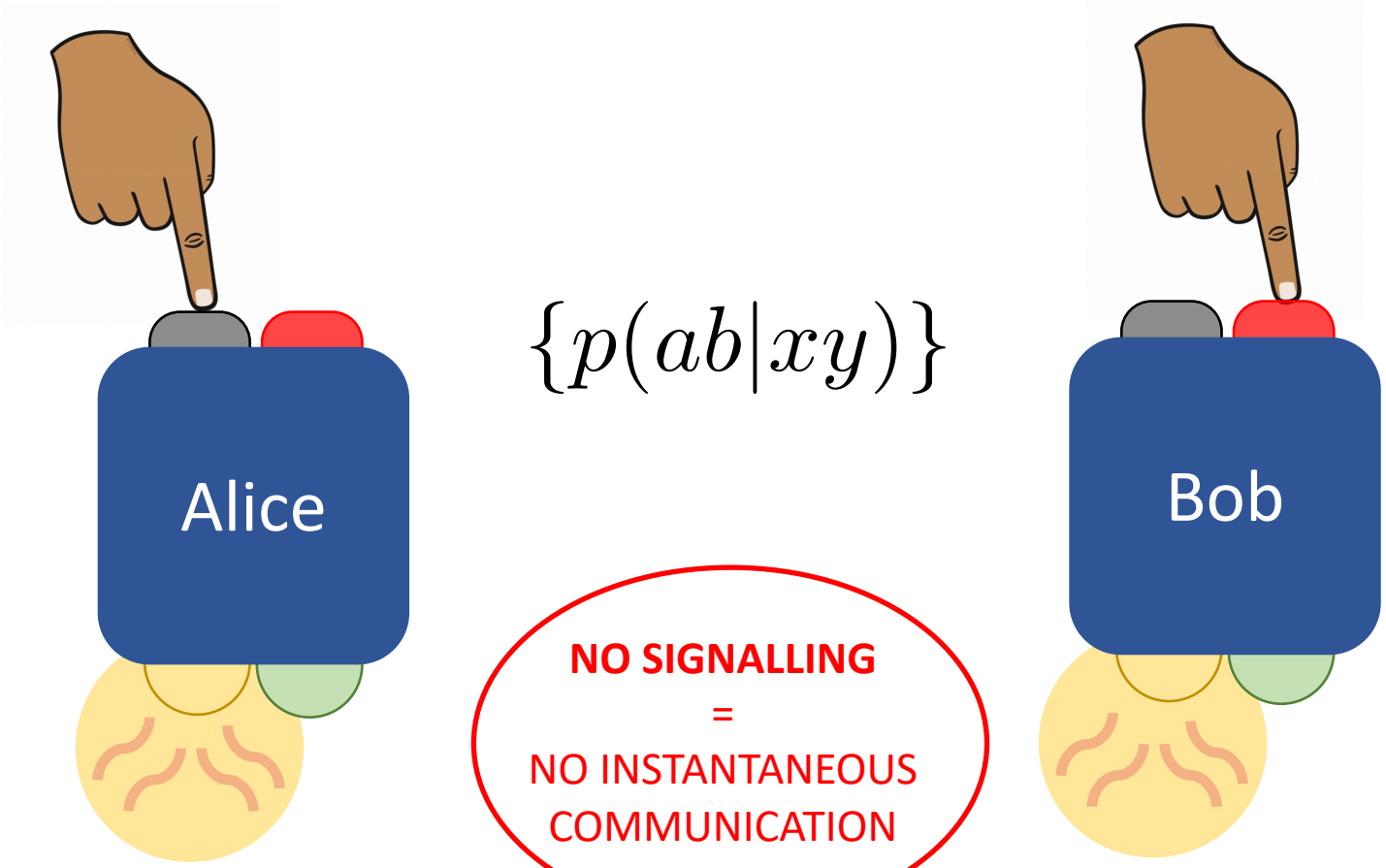
SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results



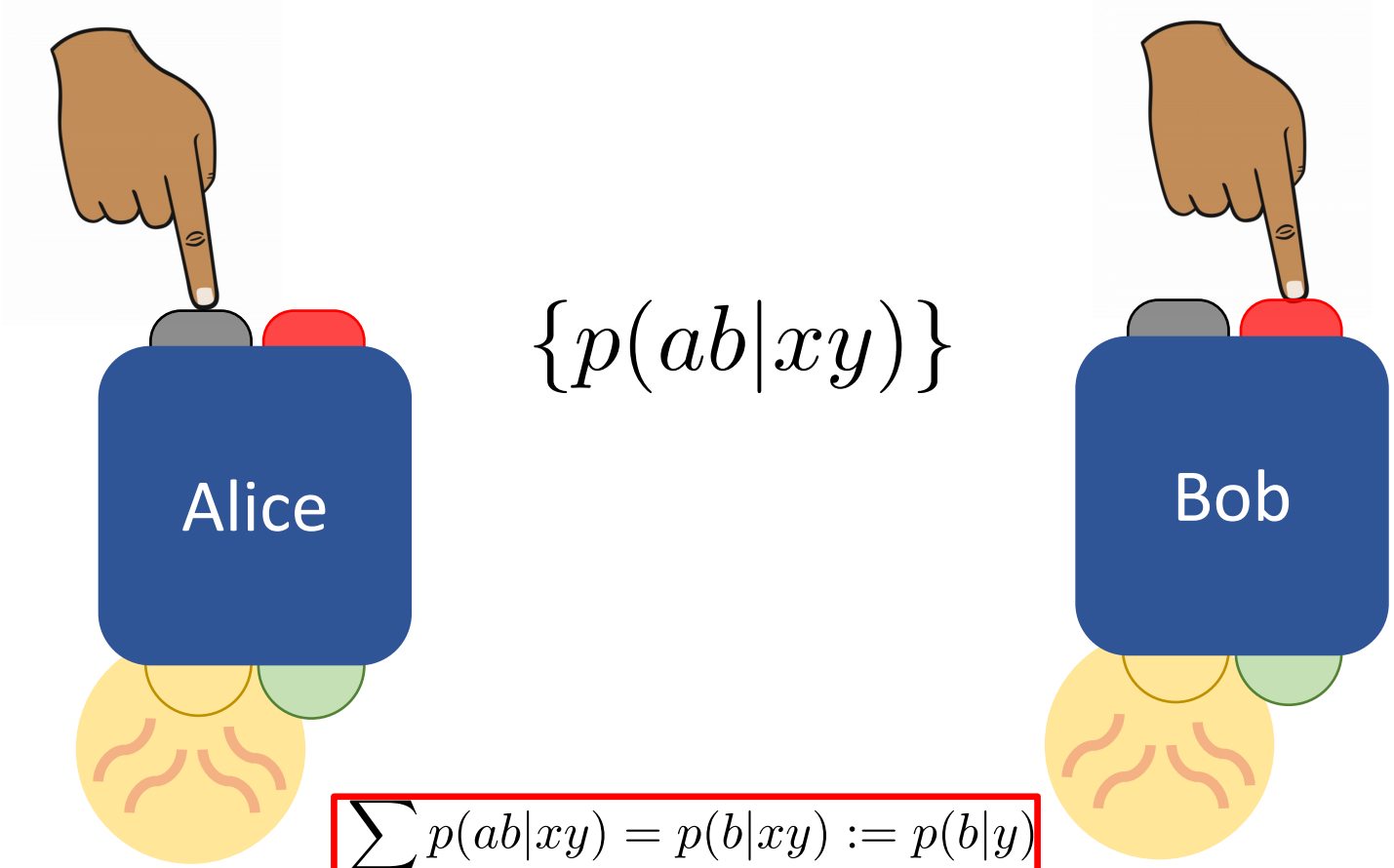
SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results



SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: a basic way to think about experimental results



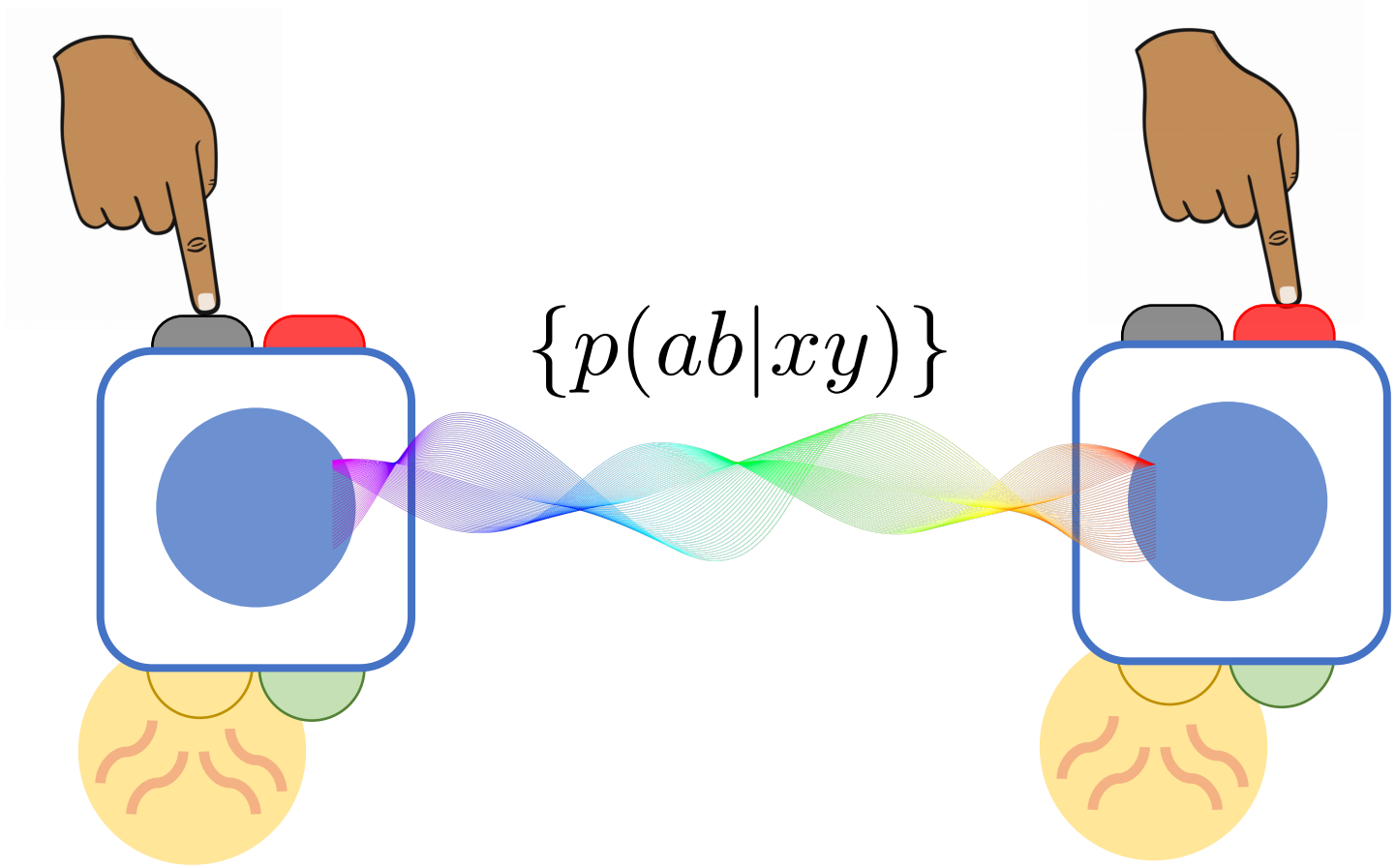
$$\{p(ab|xy)\}$$

$$\sum_a p(ab|xy) = p(b|xy) := p(b|y)$$

$$\sum_b p(ab|xy) = p(a|xy) := p(a|x)$$

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

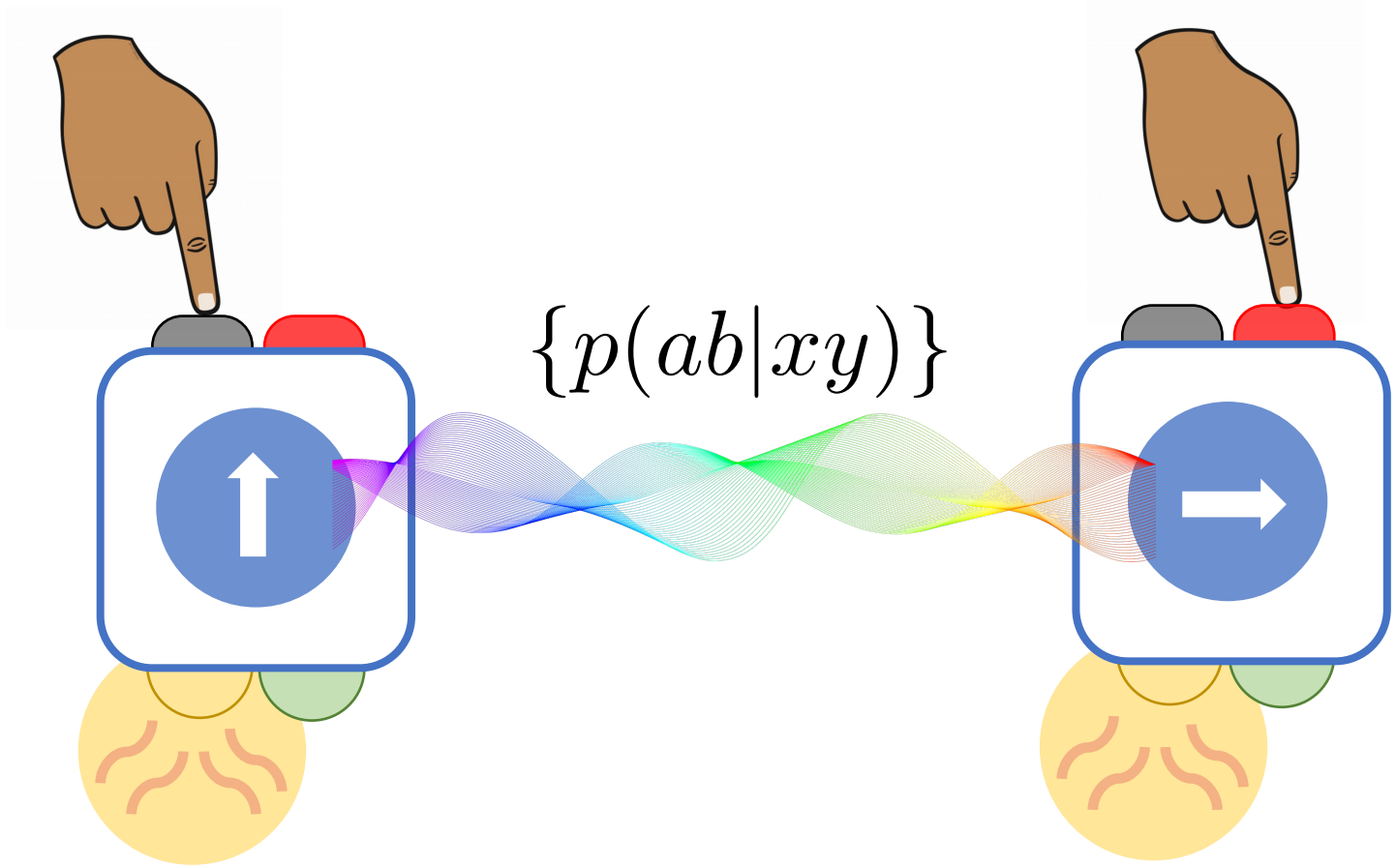
Black box scenario: quantum



NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

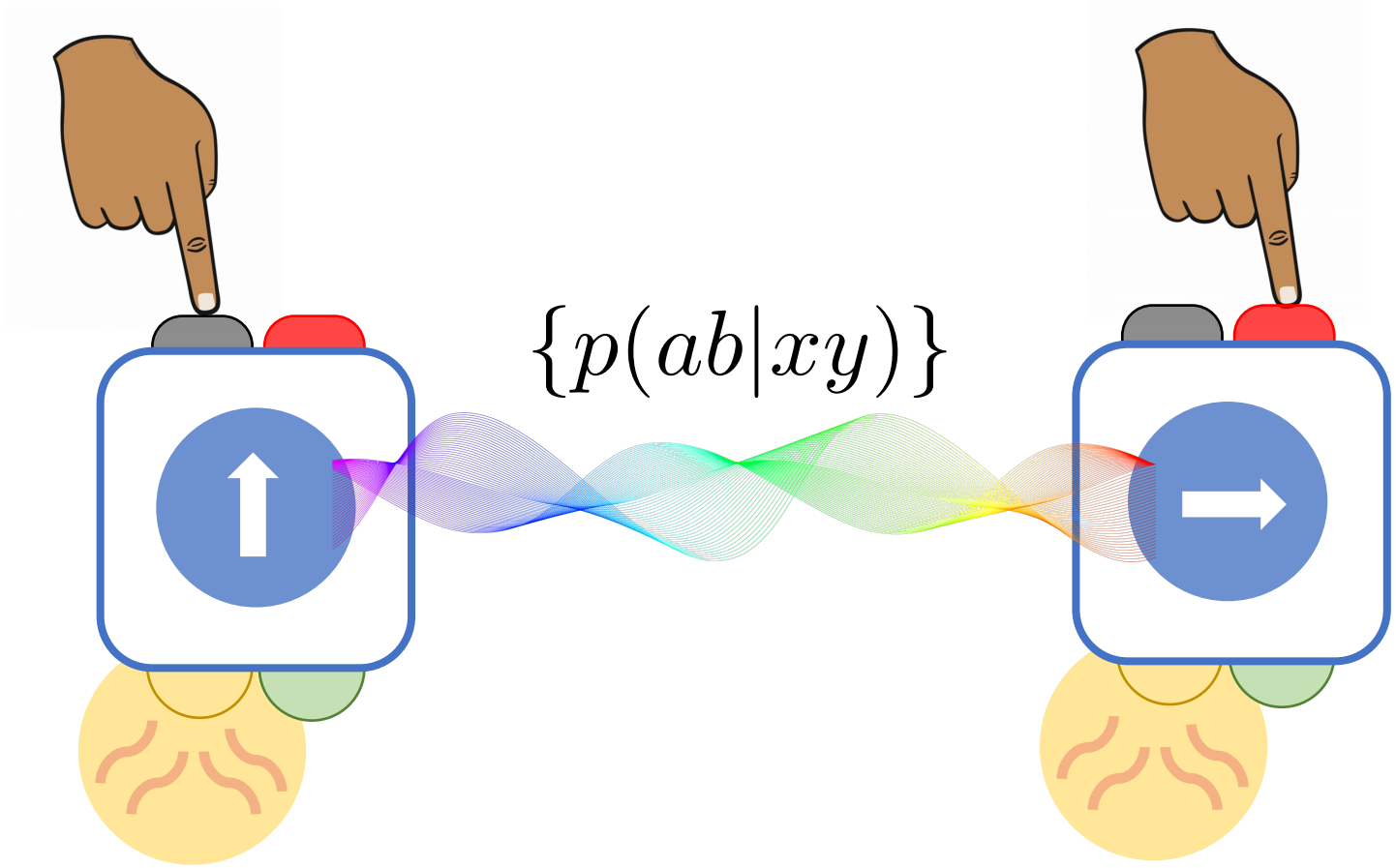
Black box scenario: quantum



NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

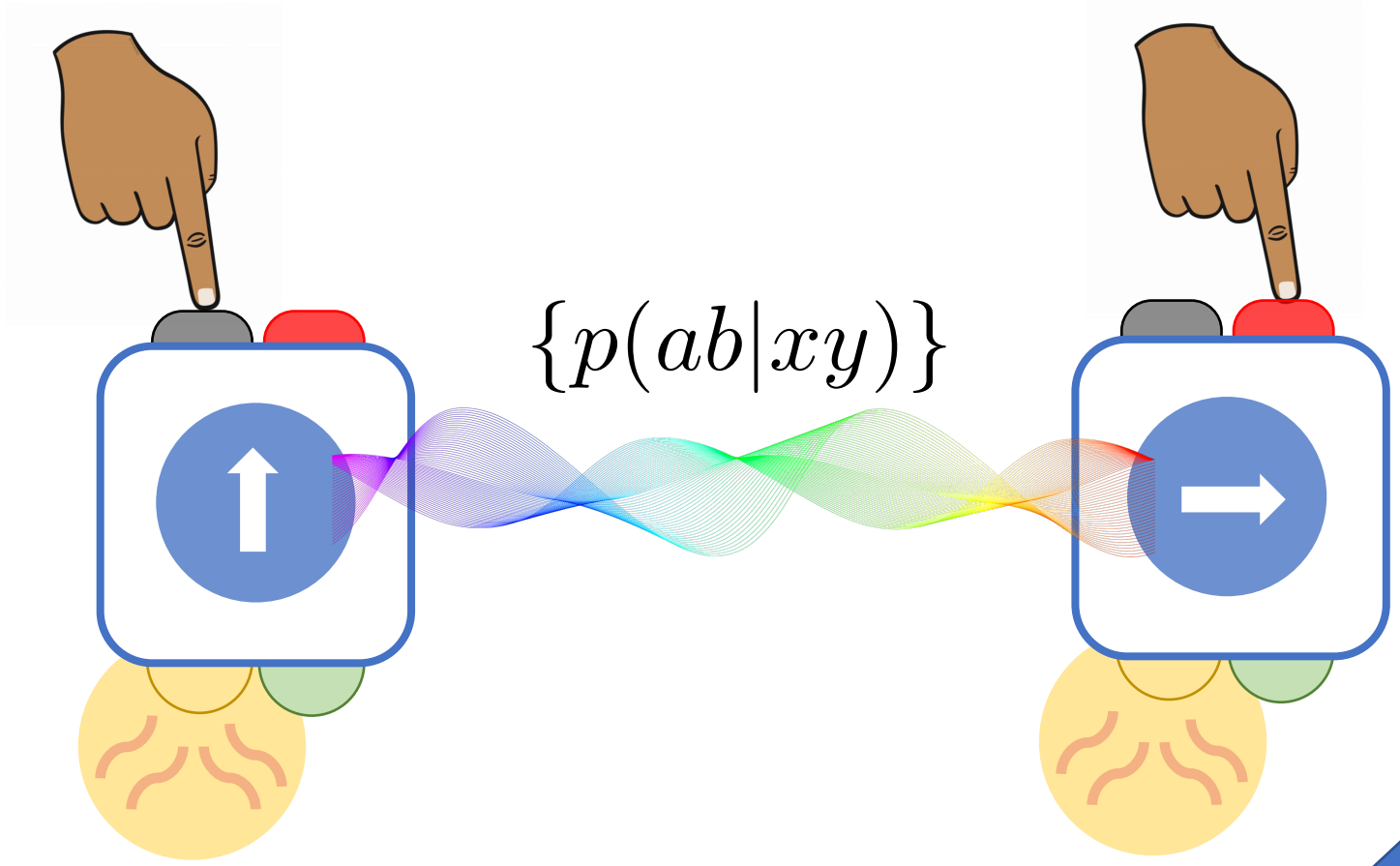
Black box scenario: quantum



NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: quantum



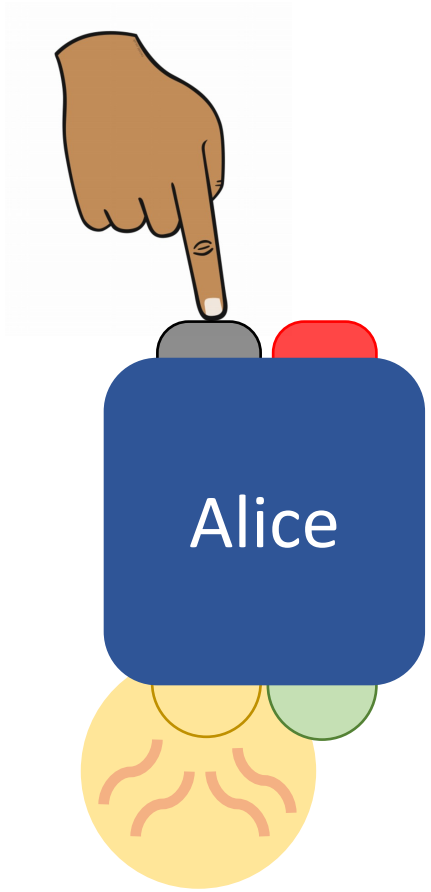
BORN RULE

$$p(ab|xy) = tr(\rho_{AB}\, M_{a|x} \otimes M_{b|y})$$

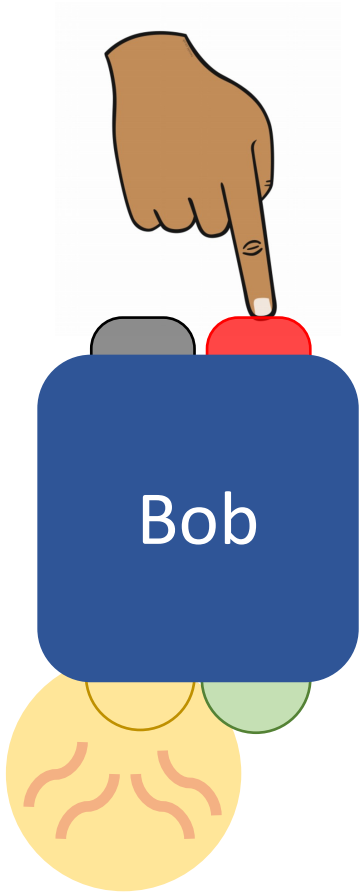
NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: local (classical) physics



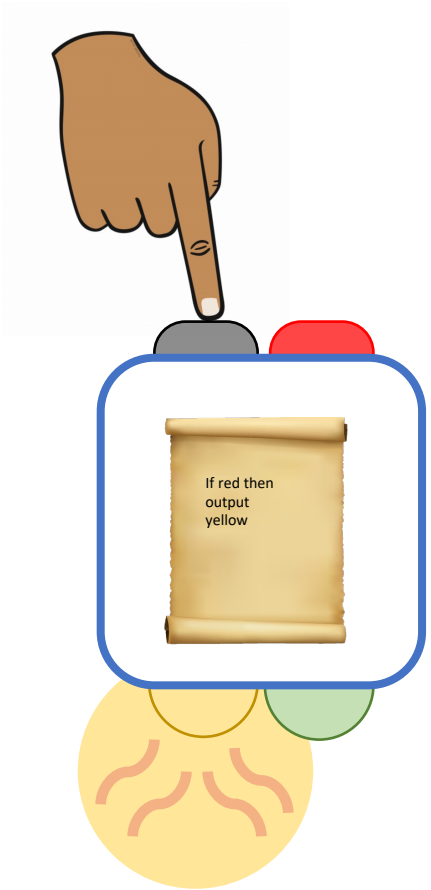
$$\{p(ab|xy)\}$$



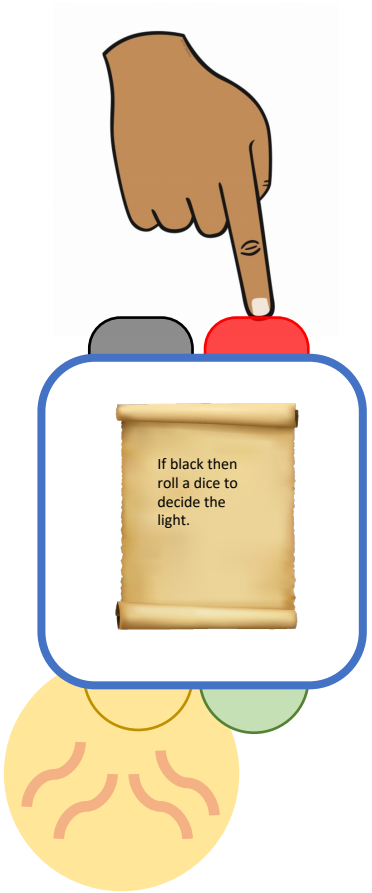
NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: local (classical) physics



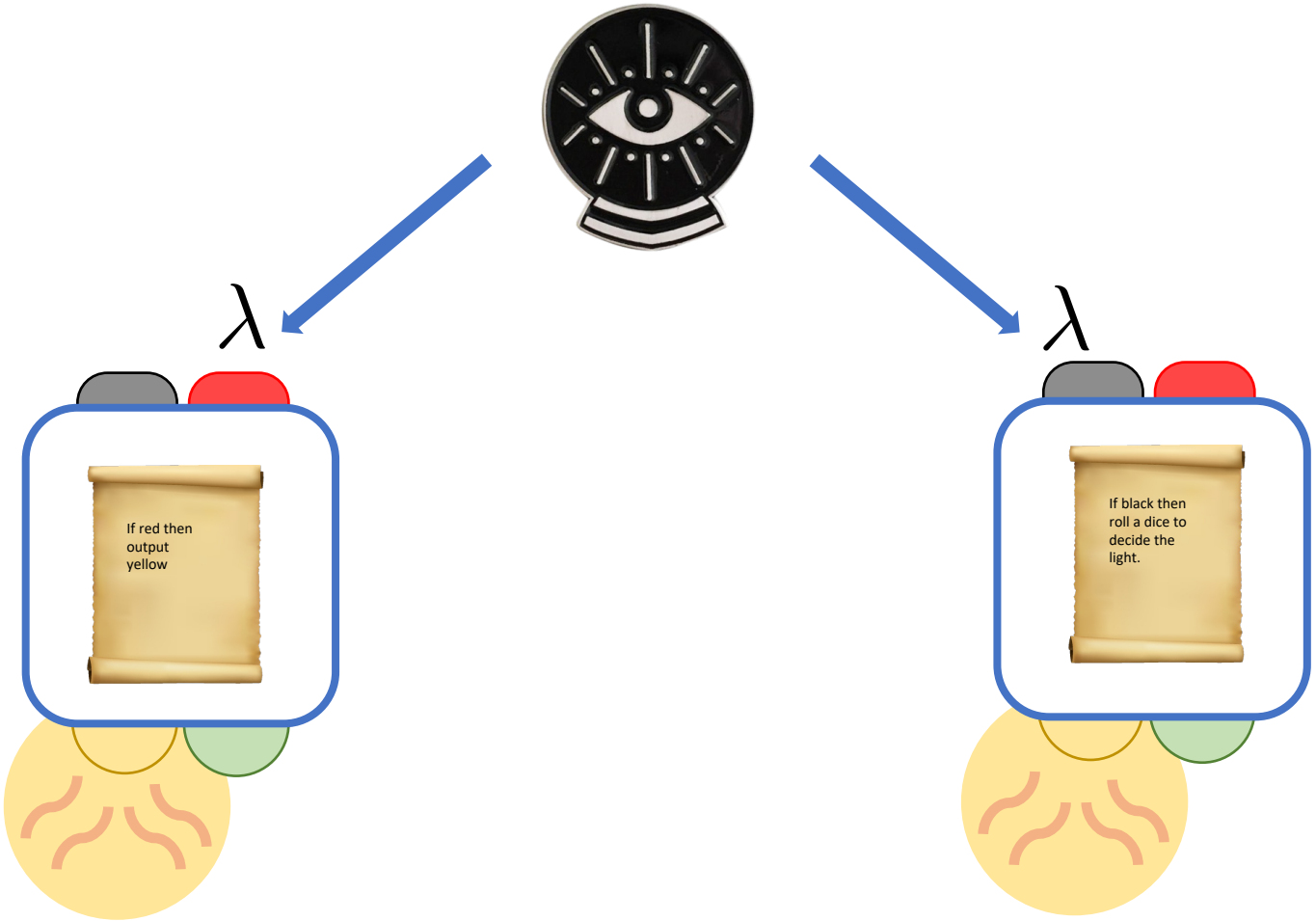
$$\{p(ab|xy)\}$$



NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: local hidden variable



$$p(ab|xy) = \sum_{\lambda} \pi_{\lambda}\, p(a|x,\lambda)p(b|y,\lambda)$$

NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: local hidden variable



There exist quantum correlations that cannot be written using the local model !

Physics Vol. 1, No. 3, pp. 195–200, 1964 Physics Publishing Co. Printed in the United States

ON THE EINSTEIN PODOLSKY ROSEN PARADOX*

J. S. BELL†
Department of Physics, University of Wisconsin, Madison, Wisconsin

(*Received* 4 *November* 1964)

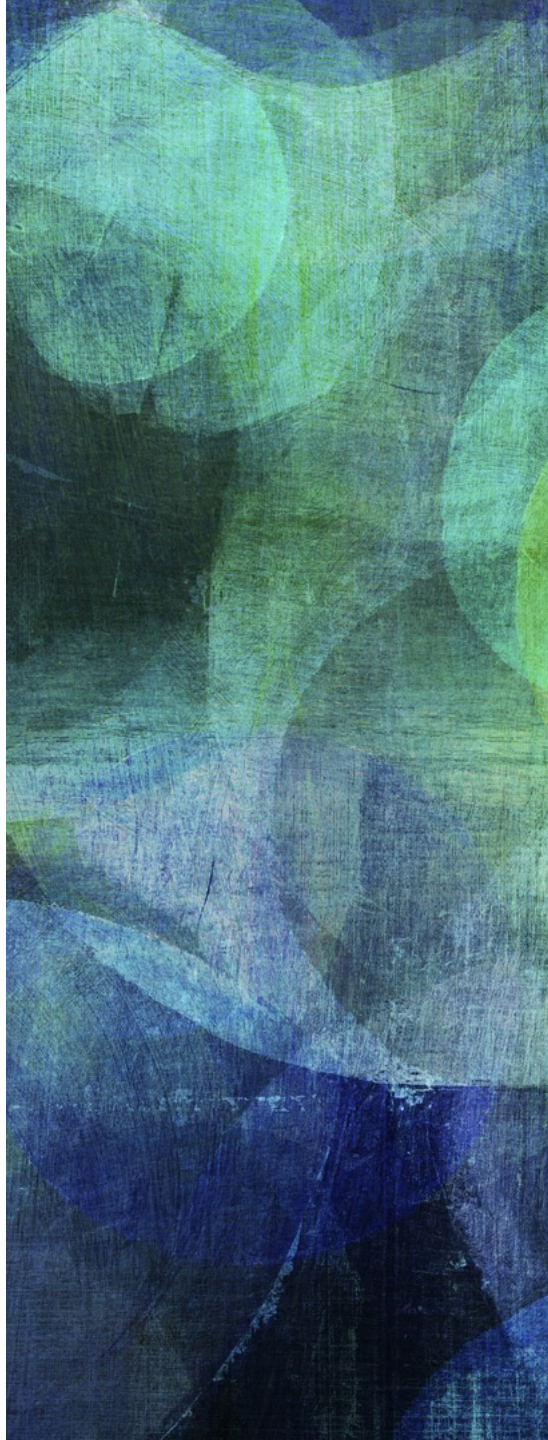
I. Introduction

THE paradox of Einstein, Podolsky and Rosen [1] was advanced as an argument that quantum mechanics could not be a complete theory but should be supplemented by additional variables. These additional variables were to restore to the theory causality and locality [2]. In this note that idea will be formulated mathematically and shown to be incompatible with the statistical predictions of quantum mechanics. It is the requirement of locality, or more precisely that the result of a measurement on one system be unaffected by operations on a distant system with which it has interacted in the past, that creates the essential difficulty. There have been attempts [3] to show that even without such a separability or locality requirement no "hidden variable" interpretation of quantum mechanics is possible. These attempts have been examined elsewhere [4] and found wanting. Moreover, a hidden variable interpretation of elementary quantum theory [5] has been explicitly constructed. That particular interpretation has indeed a grossly nonlocal structure. This is characteristic, according to the result to be proved here, of any such theory which reproduces exactly the quantum mechanical predictions.

$$p(ab|xy) = tr(\rho_{AB} M_{a|x} \otimes M_{b|y})$$
$$\neq \sum_{\lambda} \pi_{\lambda}\, p(a|x,\lambda) p(b|y,\lambda)$$

J. S. Bell, Physics Physique Fizika **1**, 195 (1964)

GIVEN a set of correlations (experimental results) can we tell if they are quantum or not?



Geometric picture

$$\mathbf{p} = \{p(00|00), p(00|01), \cdots, p(11|11)\}$$

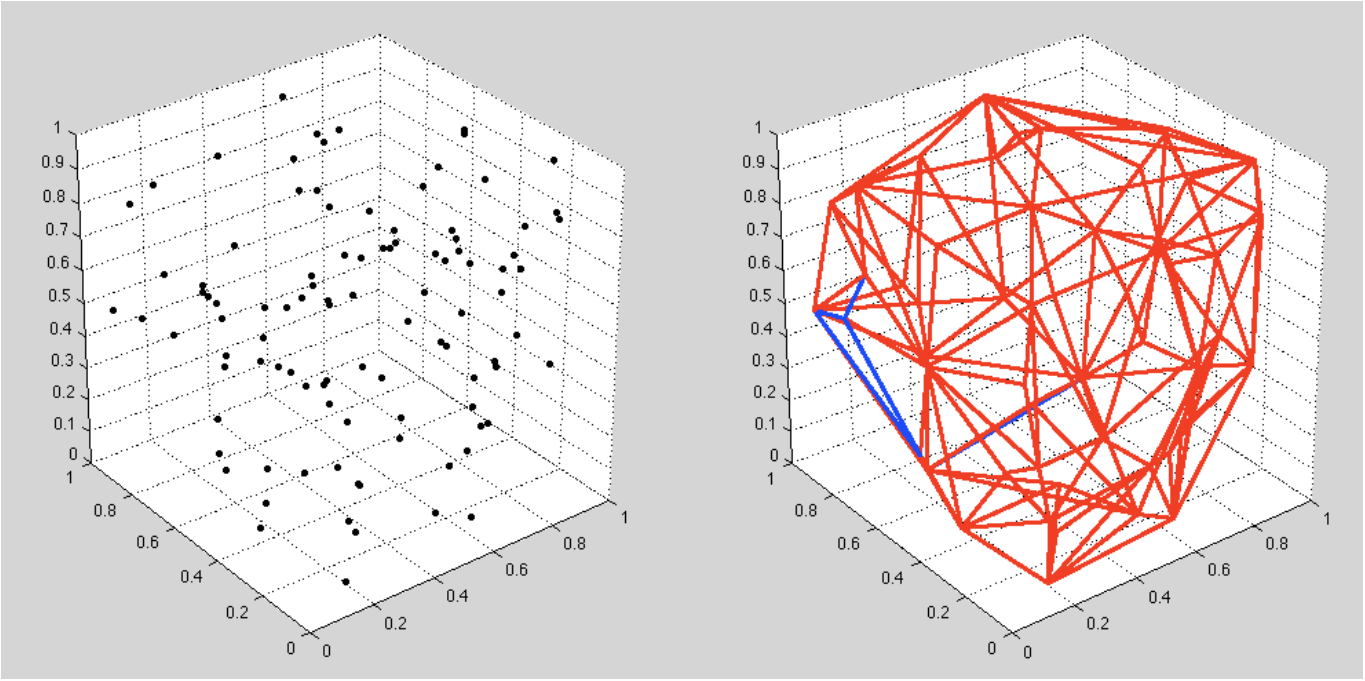
1. Take the list of probabilities p(a,b|x,y) generated by the boxes and put them into the components of a vector.

2. Find all possible vectors like this compatible with:
   - No-signaling rule
   - Local physics

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

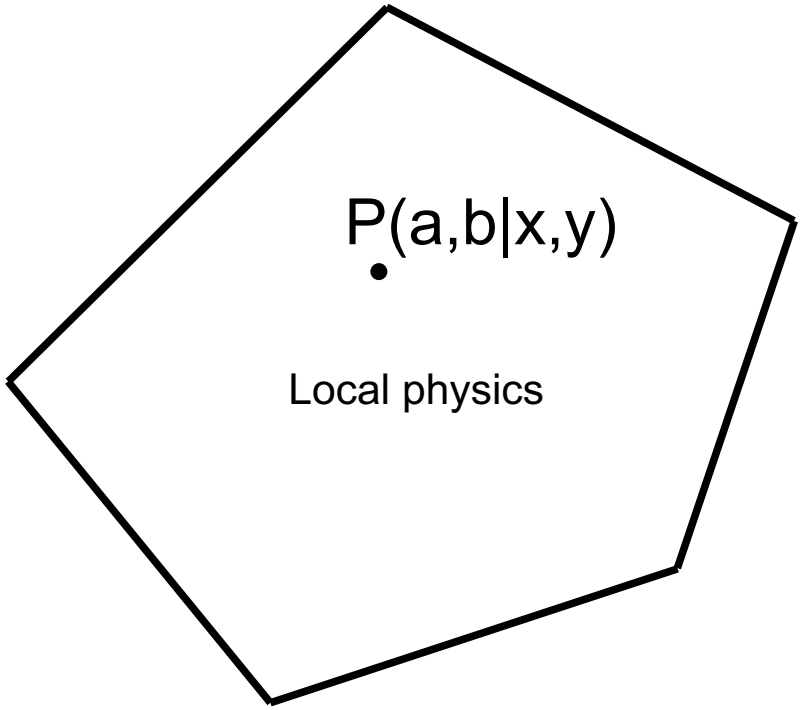
Geometric picture

$$\mathbf{p} = \{p(00|00), p(00|01), \cdots, p(11|11)\}$$



SCENARIO (2, 2, 2)
(parties, inputs, outputs)

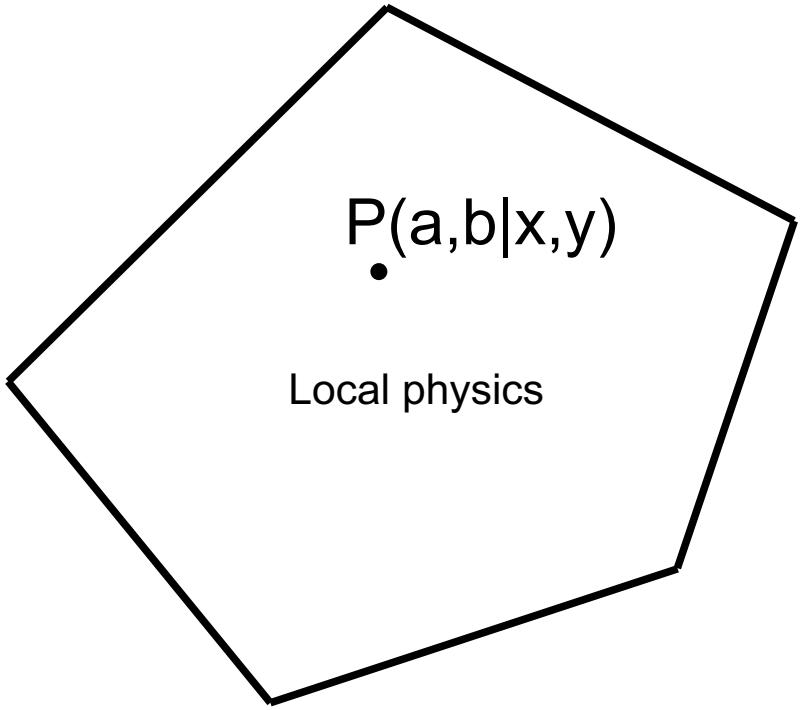
Local (classical) correlations



$$p(ab|xy) = \sum_{\lambda} \pi_\lambda \; p(a|x,\lambda)p(b|y,\lambda)$$

Form a polytope

Local (classical) correlations

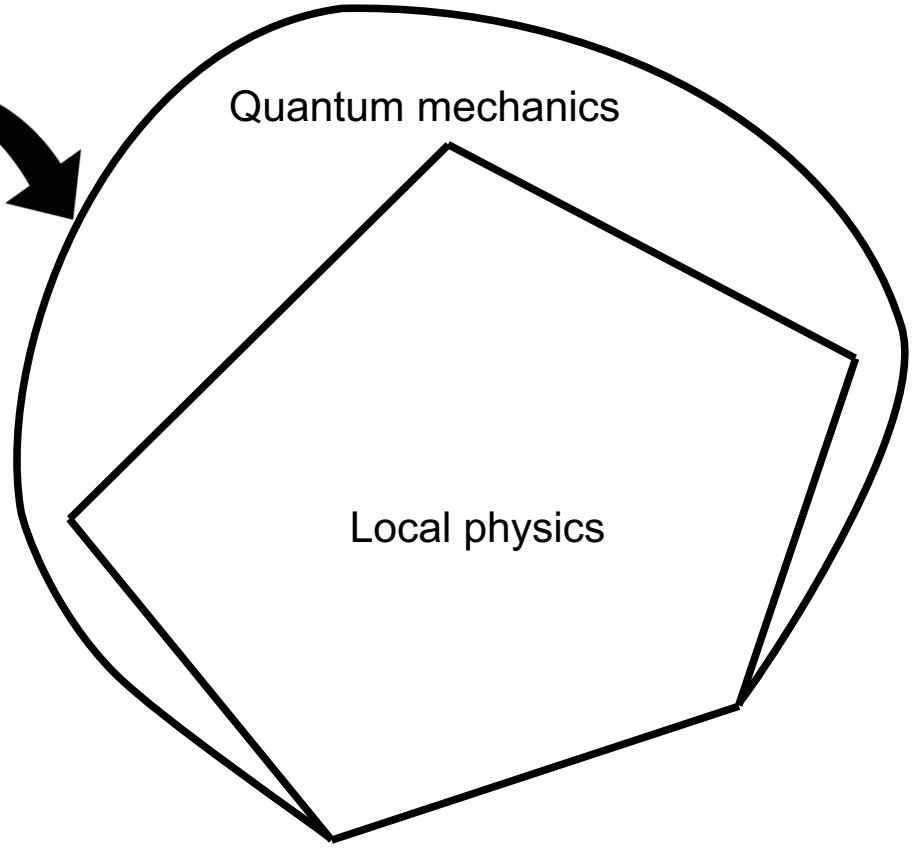


$$p(ab|xy) = \sum_{\lambda} \pi_{\lambda}\, p(a|x,\lambda)p(b|y,\lambda)$$

There exist correlations in quantum theory that **cannot** be written like this!

Quantum correlations

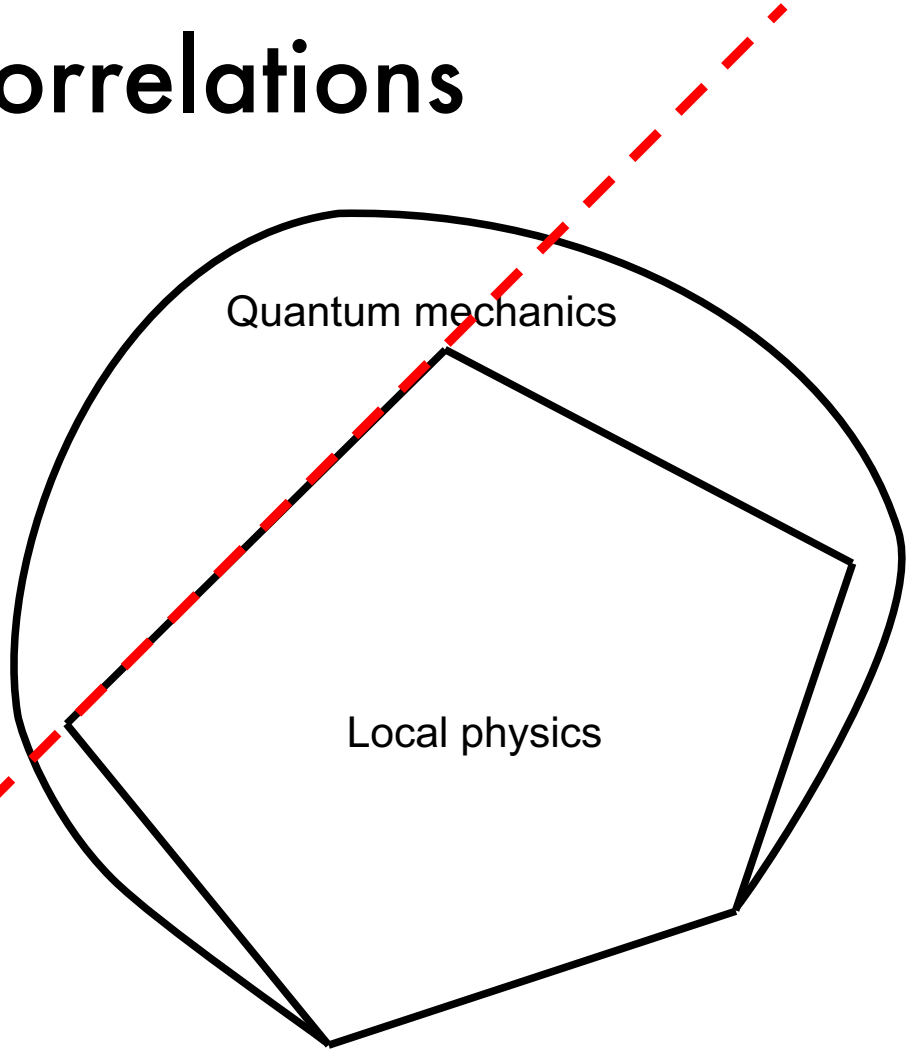
The boundary is not, in general, known!



$$p(ab|xy) = tr(\rho_{AB}\, M_{a|x} \otimes M_{b|y})$$

There exist correlations in quantum theory that **cannot** be written like this!

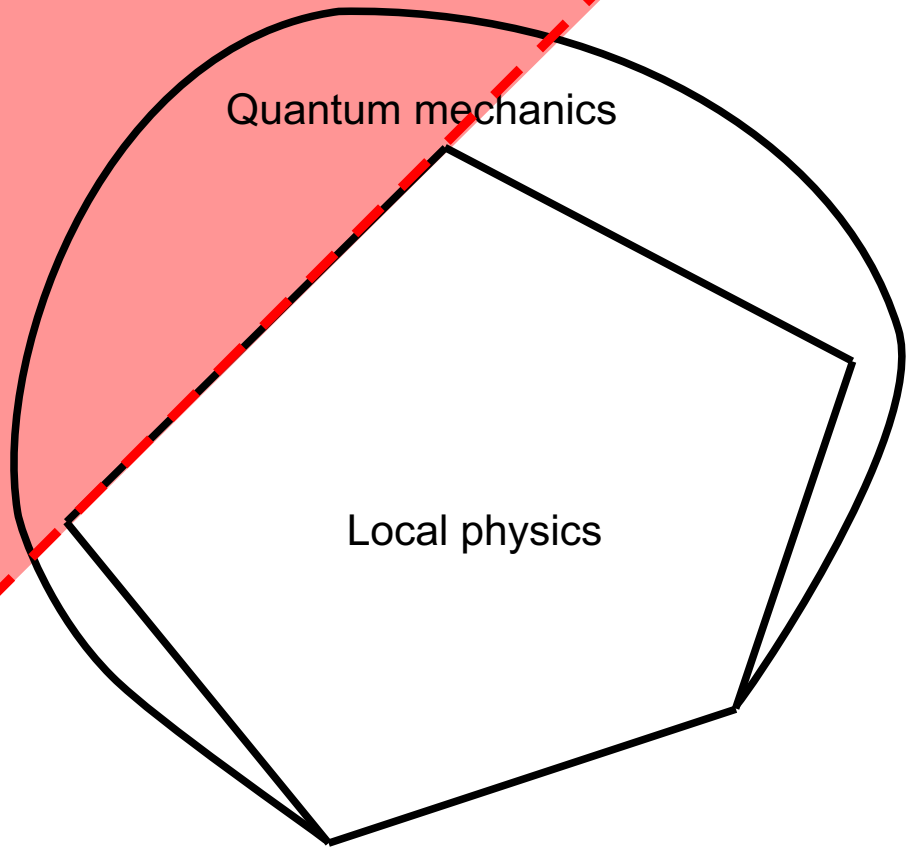
Quantum correlations



$$\sum_{a,b,x,y} c_{abxy}\, p(a,b|x,y) = k$$

There exists a hyperplane to distinguish the two sets.

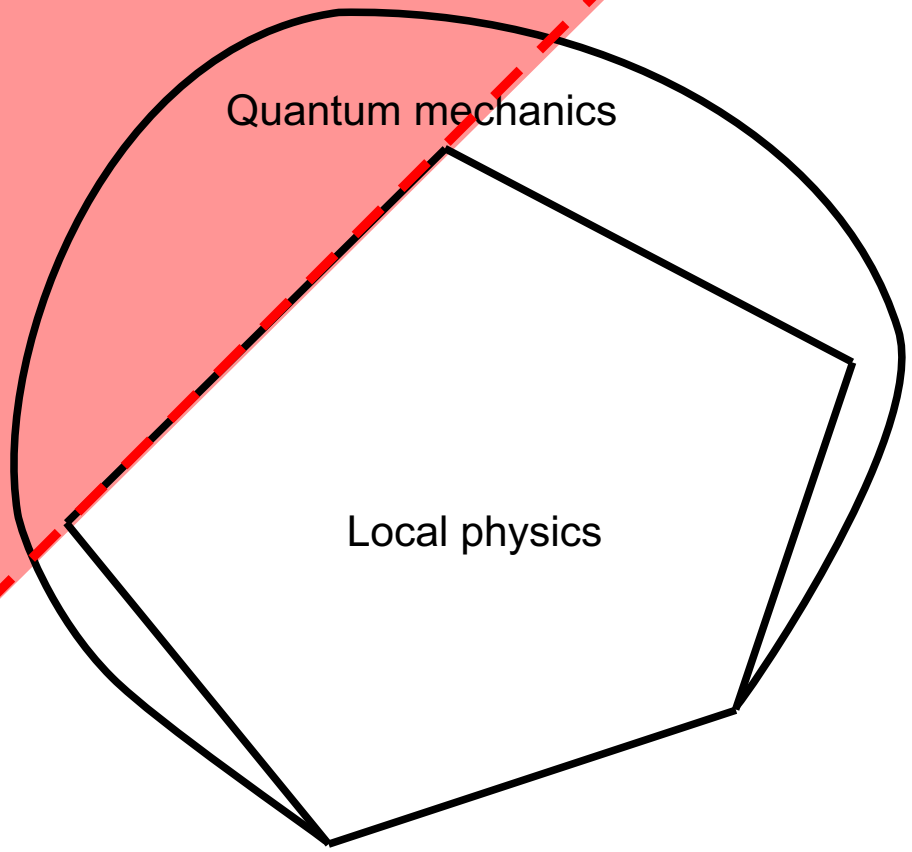
Quantum correlations



There exists a hyperplane to distinguish the two sets.

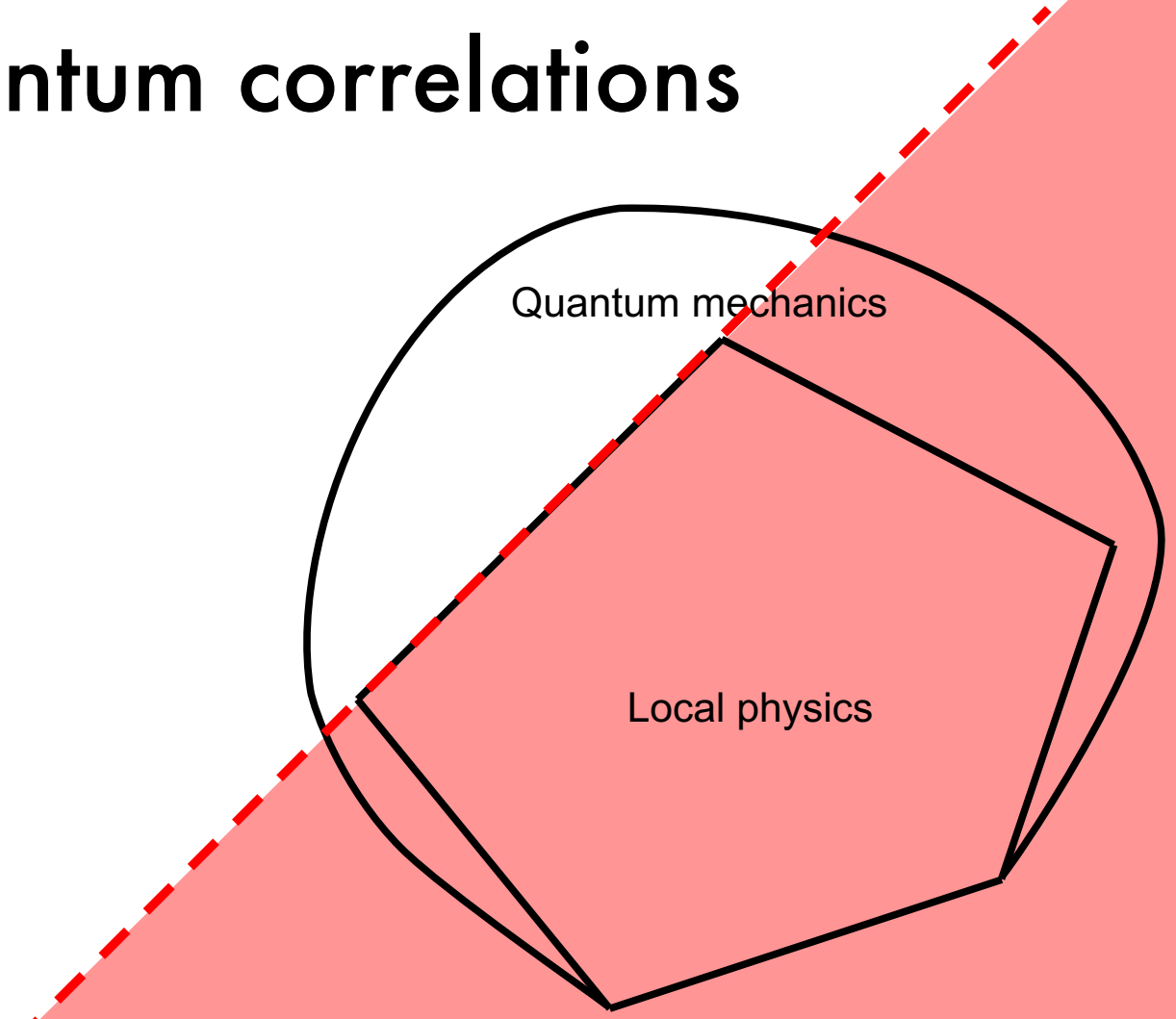
Quantum correlations

NOT LOCAL PHYSICS



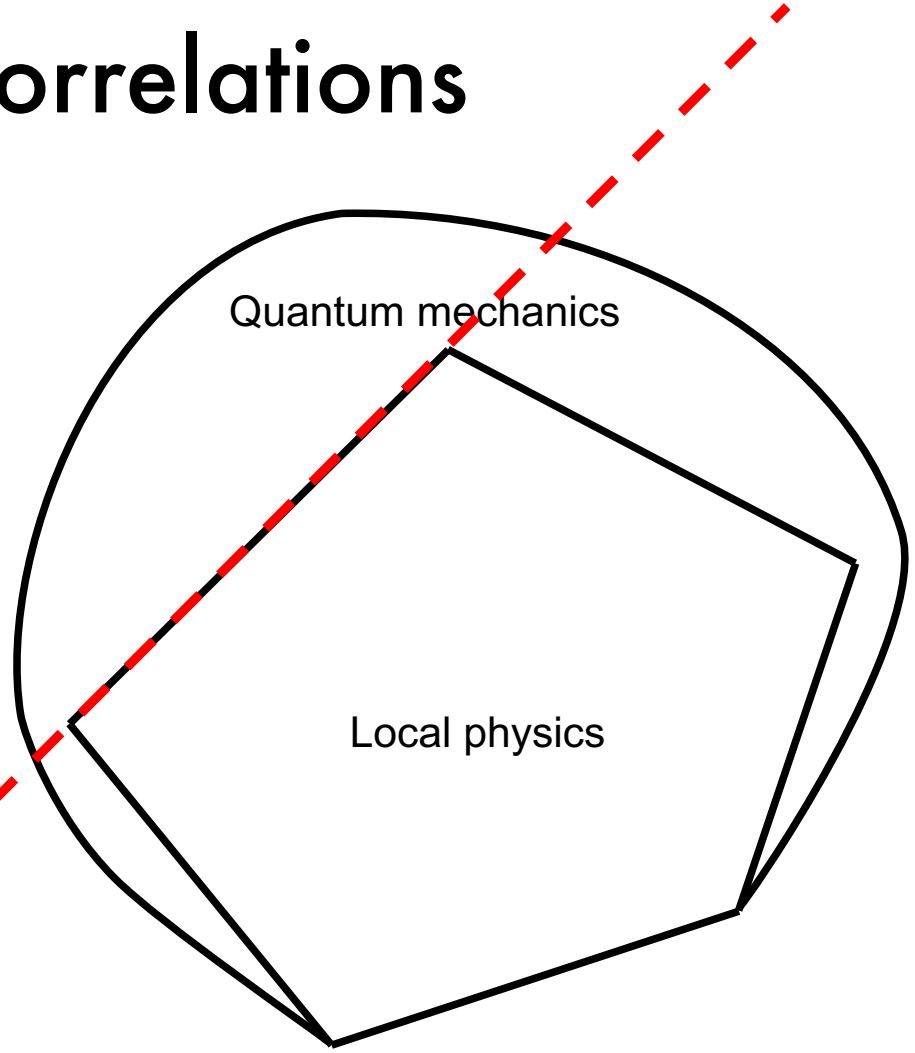
There exists a hyperplane to distinguish the two sets.

Quantum correlations



There exists a hyperplane to distinguish the two sets. Hyperplane = an affine combination of $p(ab|xy)$, i.e. a an affine combination of experimental results.

Quantum correlations

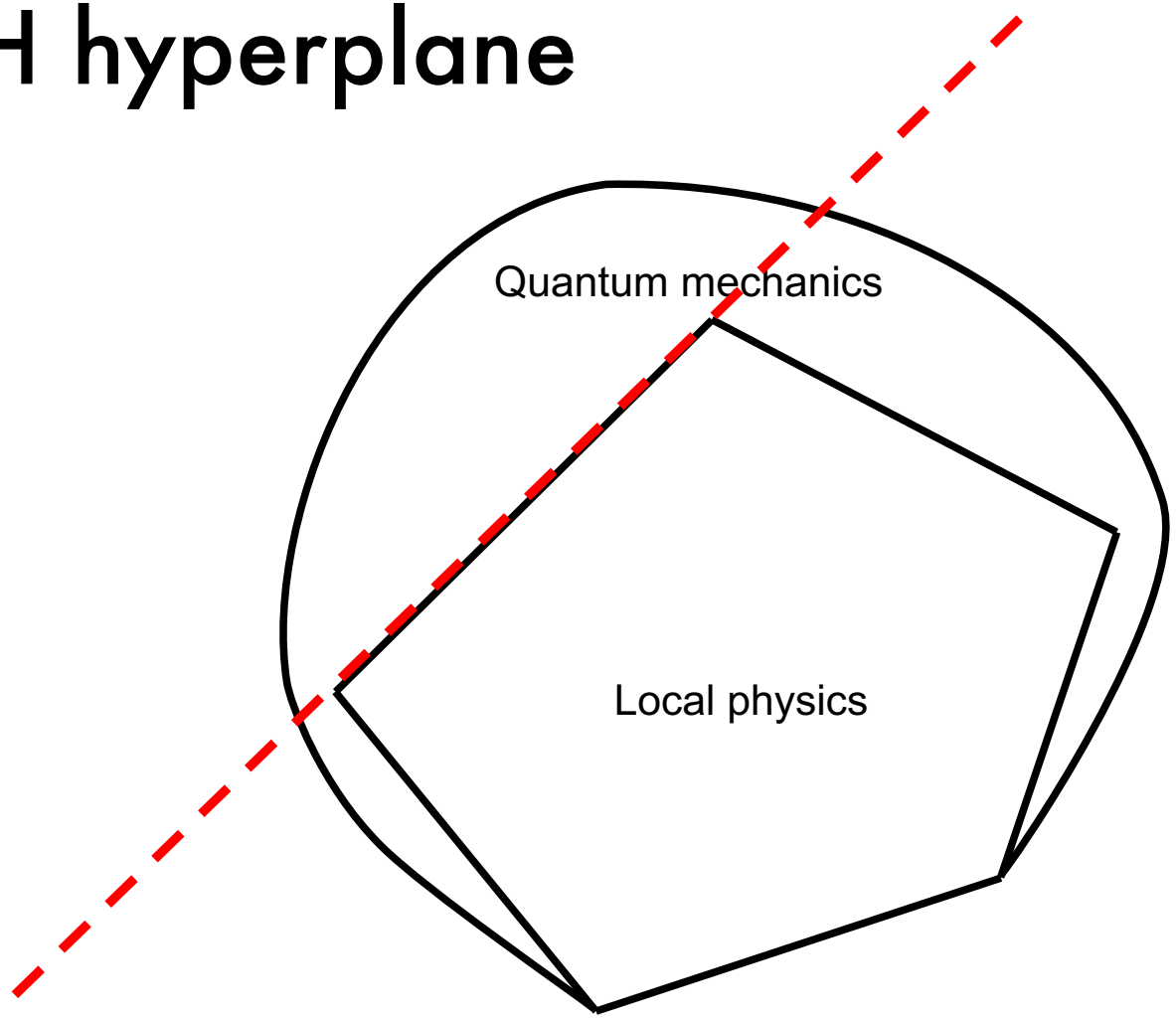


$$\sum_{a,b,x,y} c_{abxy}\, p(a,b|x,y) = k$$

BELL TEST

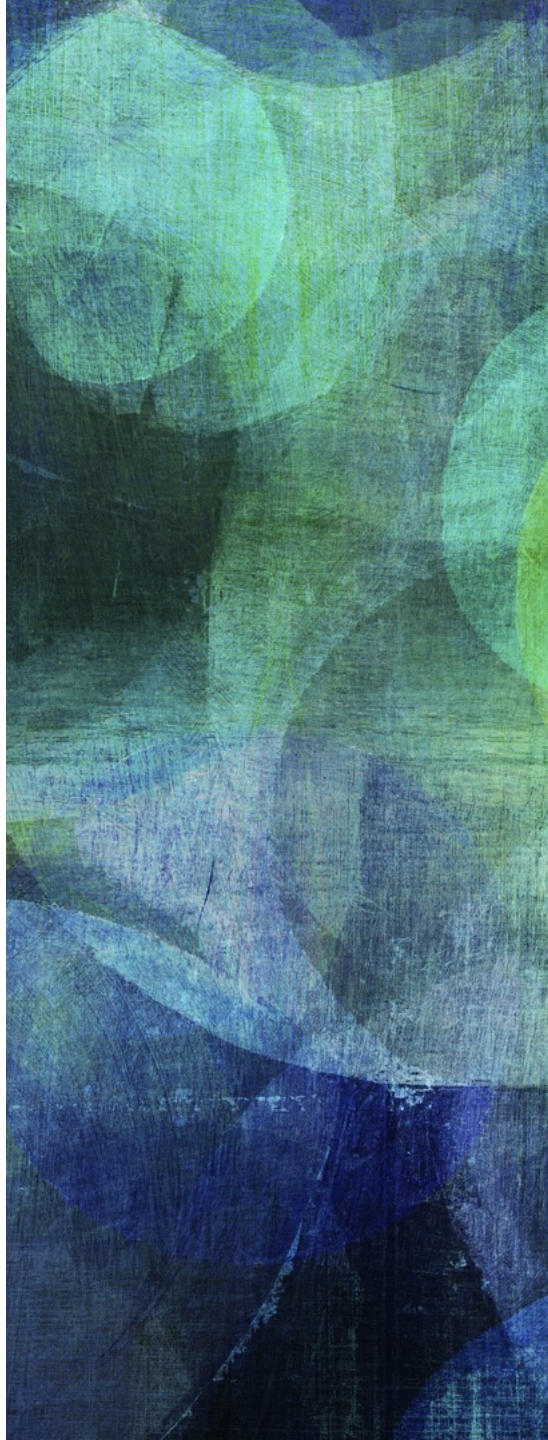
GIVEN a set of correlations, are they quantum?

CHSH hyperplane

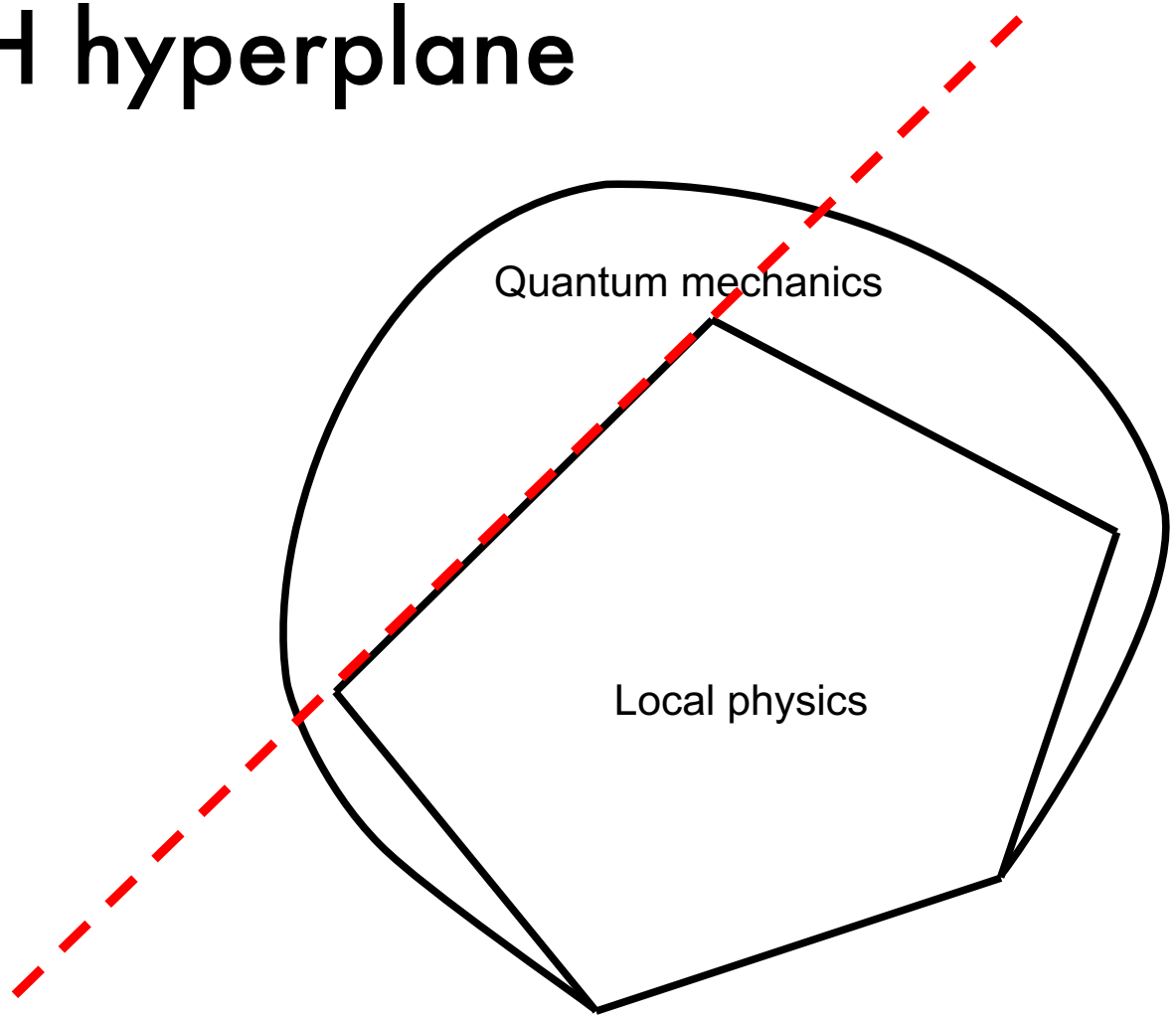


$$CHSH = \langle A_0 B_0 \rangle + \langle A_0 B_1 \rangle + \langle A_1 B_0 \rangle - \langle A_1 B_1 \rangle$$

J. F. Clauser, M. A. Horne, A. Shimony, and R. A. Holt, Phys. Rev. Lett. **23**, 880 (1969).

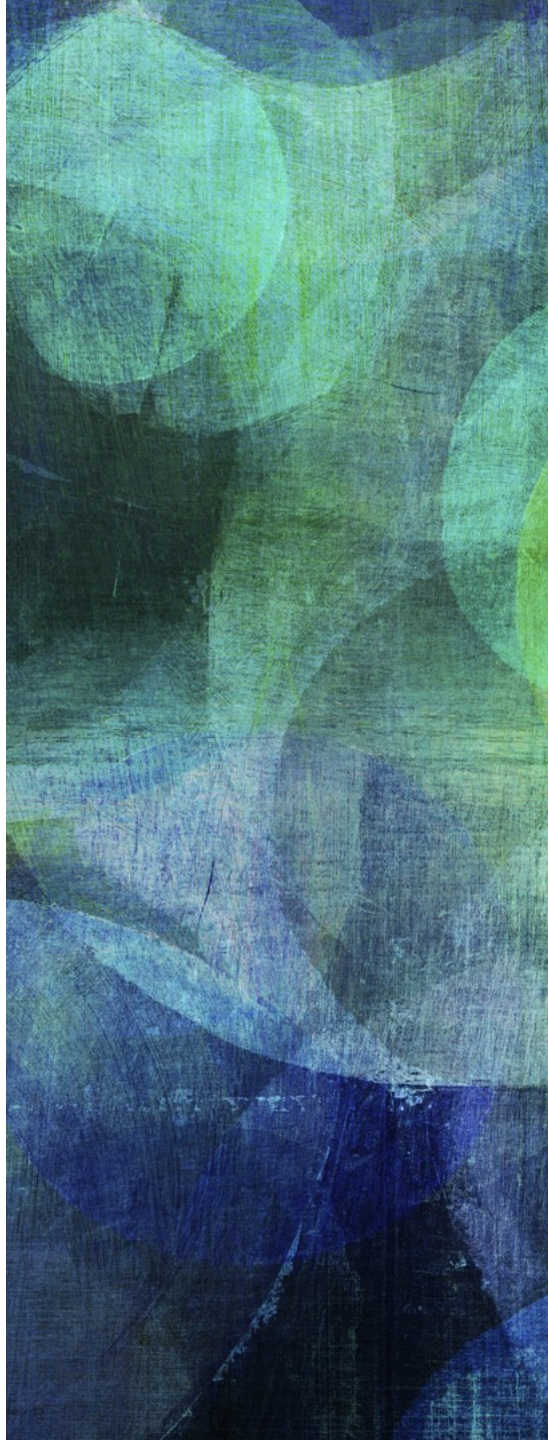


CHSH hyperplane

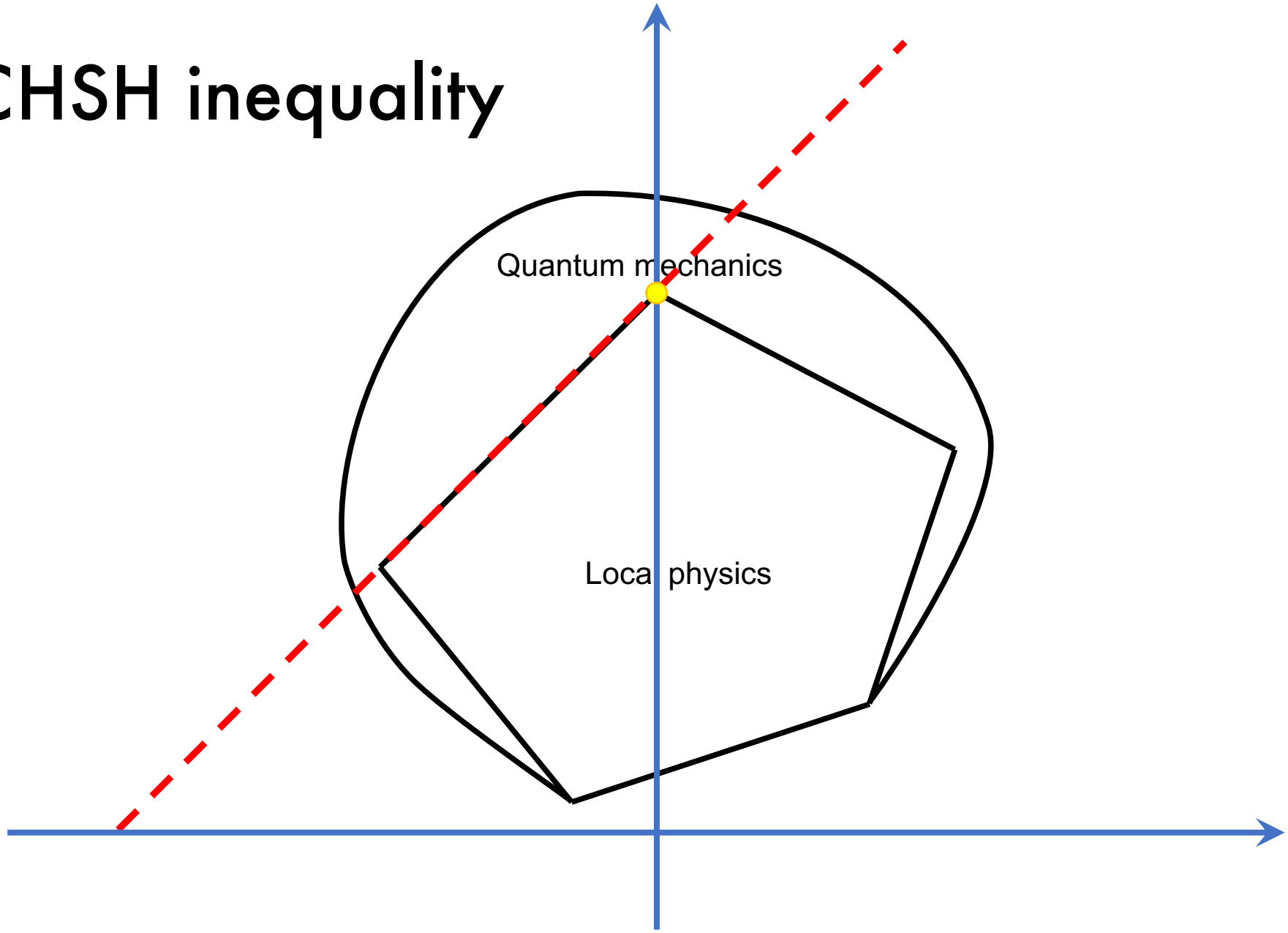


$$CHSH = p(00|00) + 2p(01|10) \cdots$$

J. F. Clauser, M. A. Horne, A. Shimony, and R. A. Holt, Phys. Rev. Lett. **23**, 880 (1969).

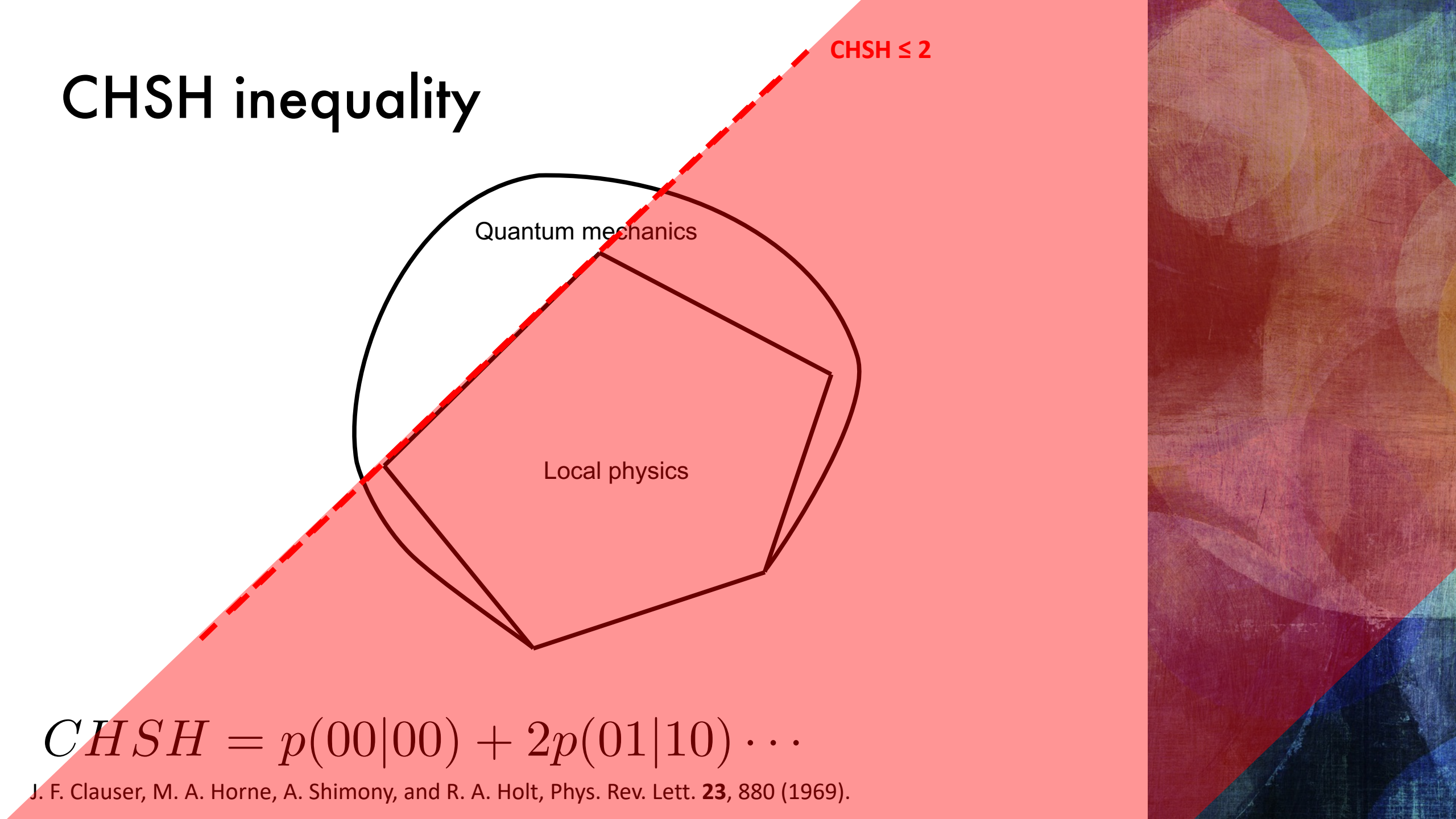


CHSH inequality



There exists a hyperplane to distinguish the two sets. Hyperplane = an affine combination of $p(ab|xy)$, i.e. a an affine combination of experimental results.

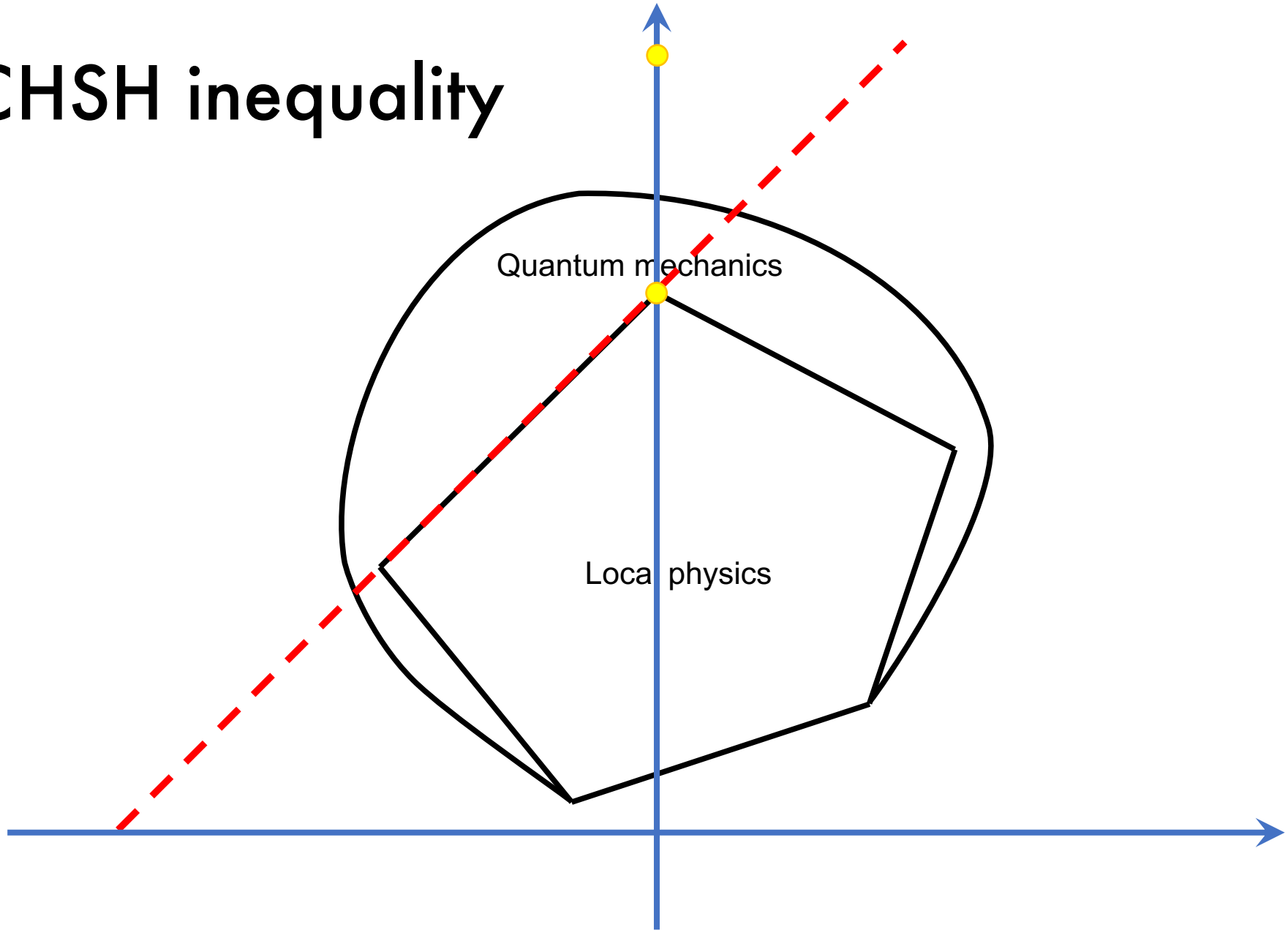
CHSH inequality



$$CHSH = p(00|00) + 2p(01|10) \cdots$$

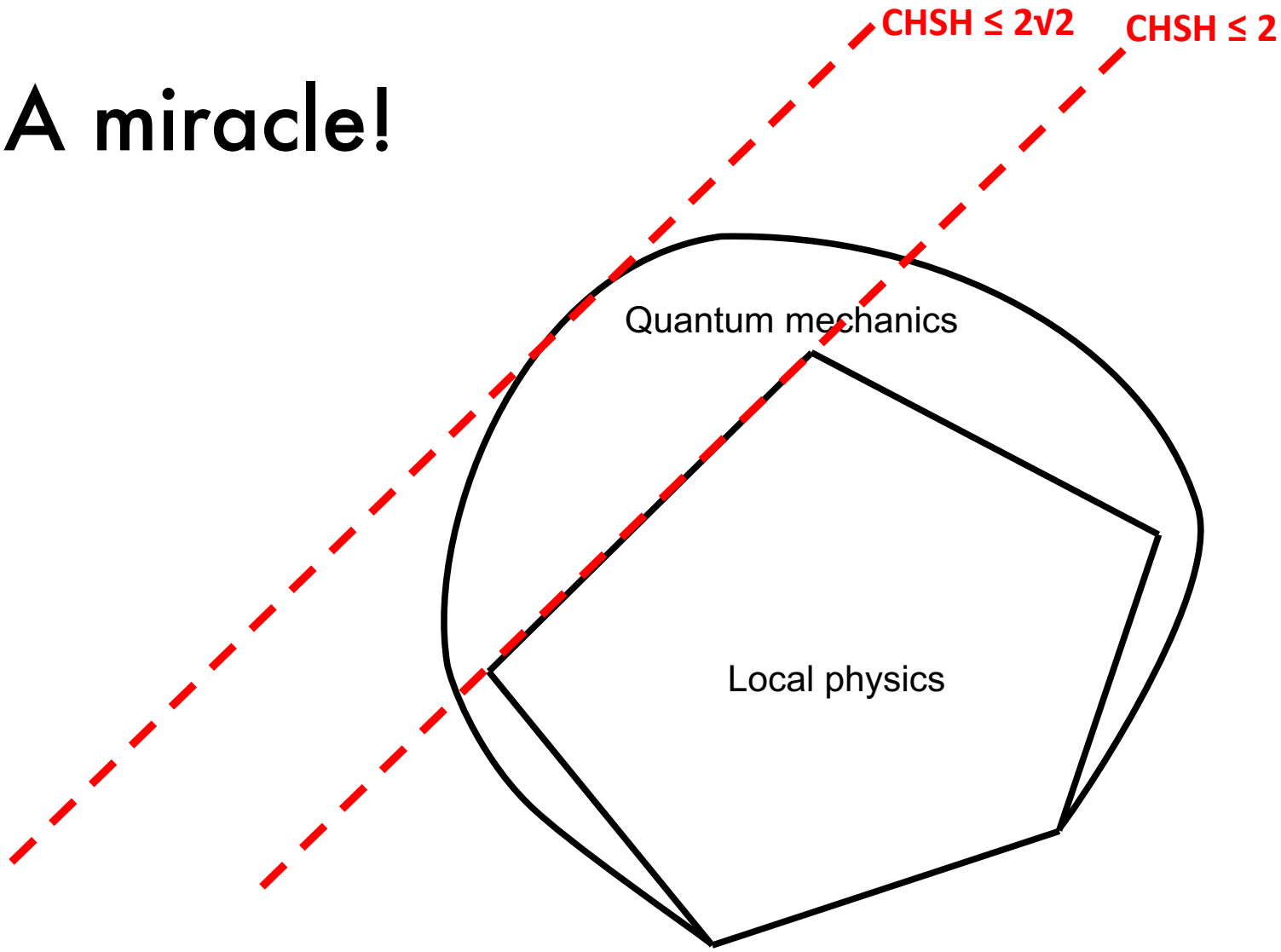
J. F. Clauser, M. A. Horne, A. Shimony, and R. A. Holt, Phys. Rev. Lett. **23**, 880 (1969).

CHSH inequality



Maximise over the quantum set

A miracle!

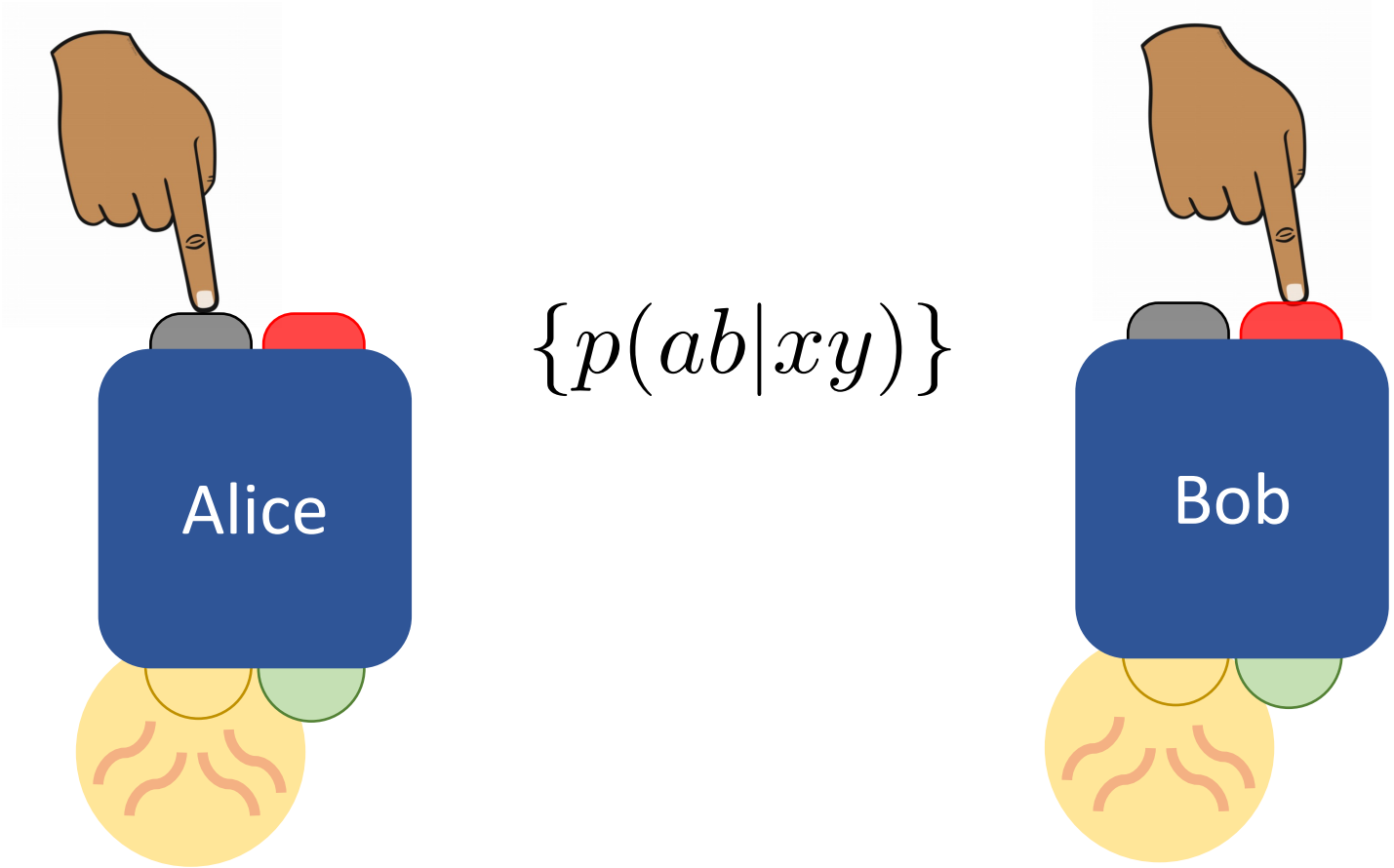


CHSH ≤ 2√2 is a global maximum over all possible quantum states and all possible measurements!

B.S. Tsirelson, Letters in Mathematical Physics 4, 93-100 (1980)

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

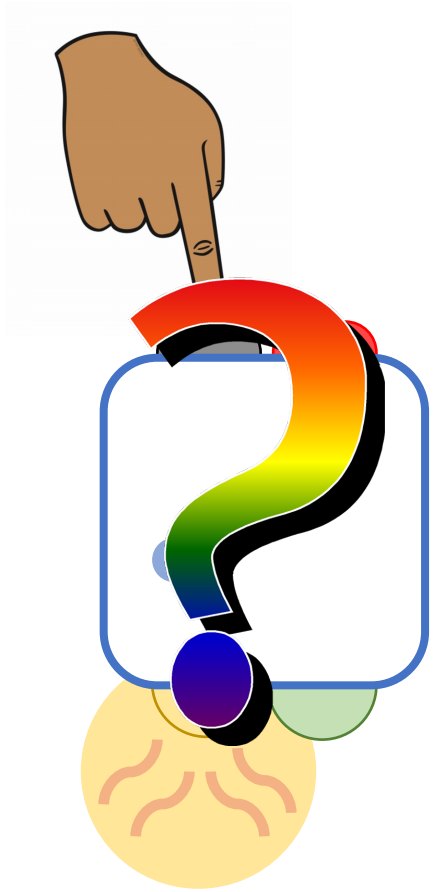
Black box scenario: no assumptions!



NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

Black box scenario: no assumptions!



$$\{p(ab|xy)\}$$

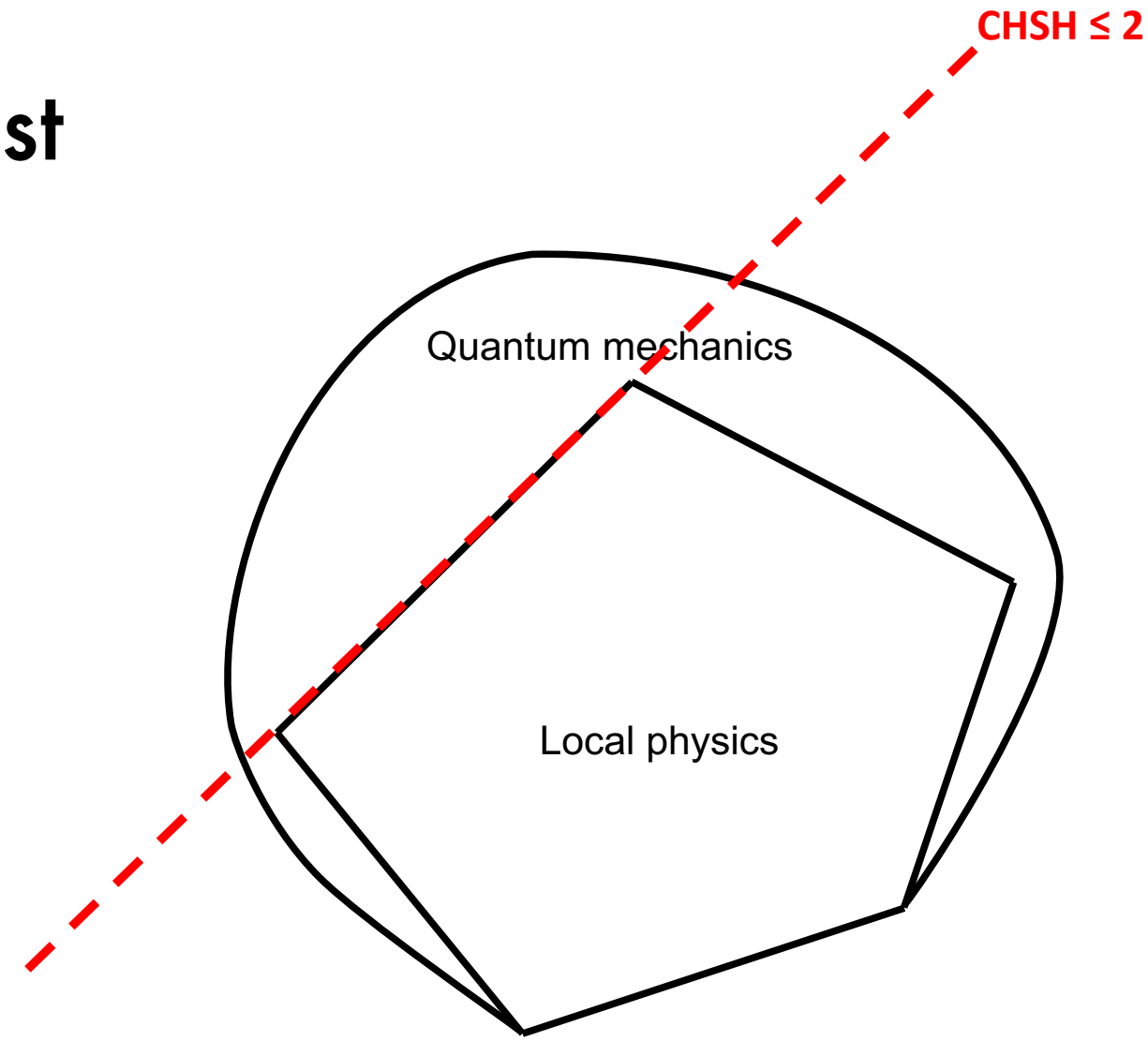


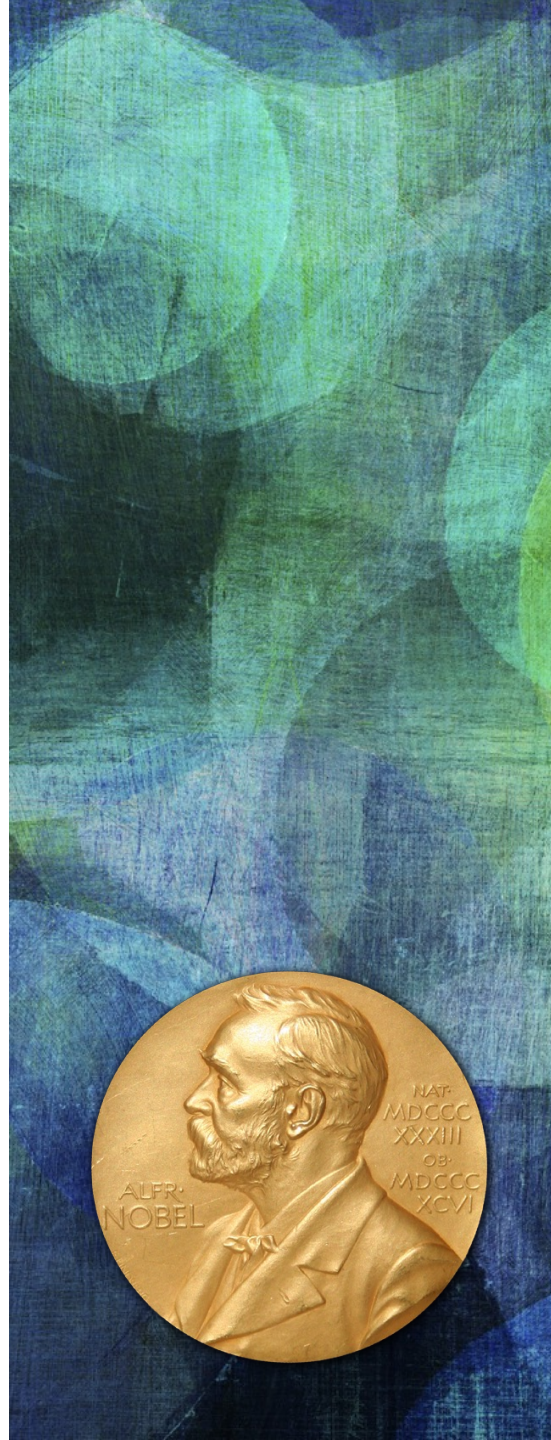
NO ASSUMPTION ON THE DIMENSION OF THE HILBERT SPACES

NO SIGNALLING

SCENARIO (2, 2, 2)
(parties, inputs, outputs)

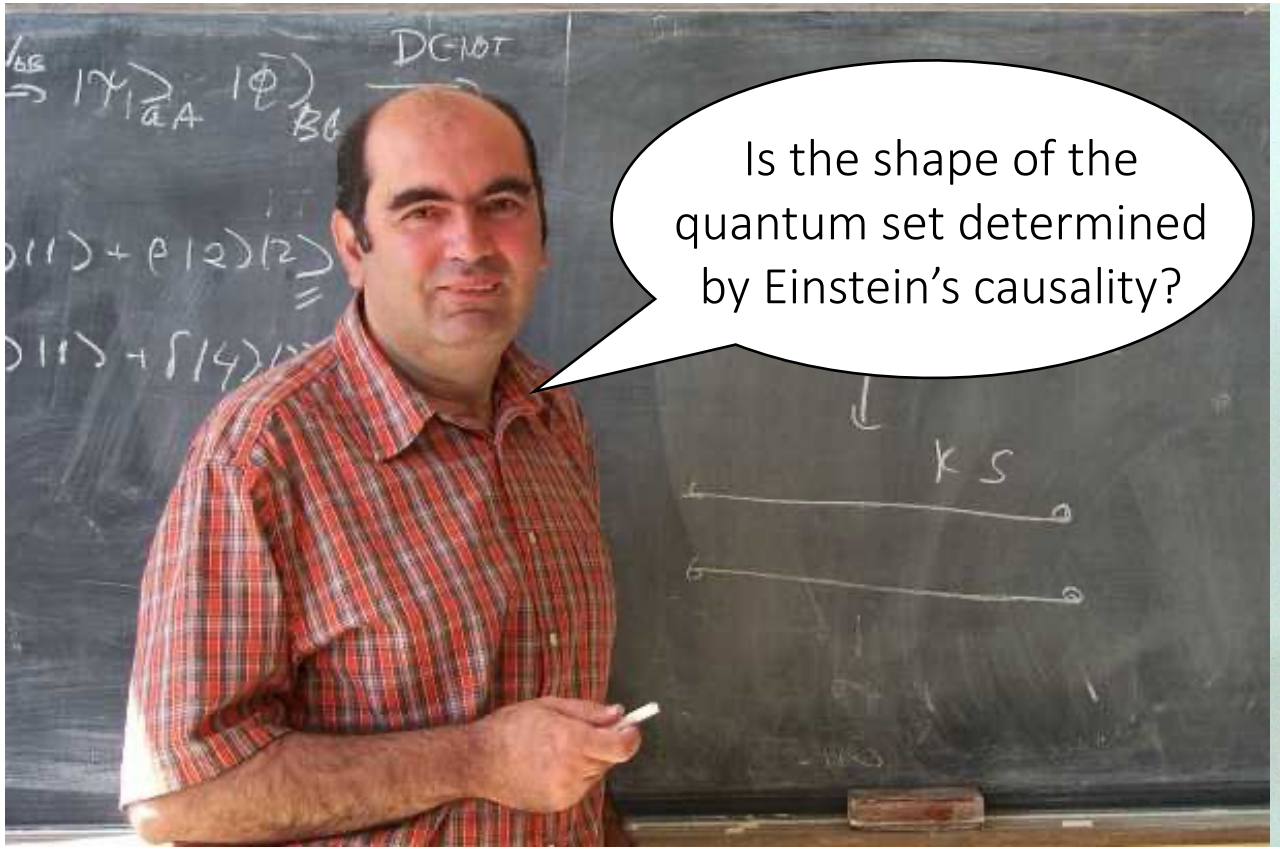
Bell test





The Nobel Prize in Physics 2022 was awarded to Alain Aspect, John F. Clauser and Anton Zeilinger “for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science”.

1994



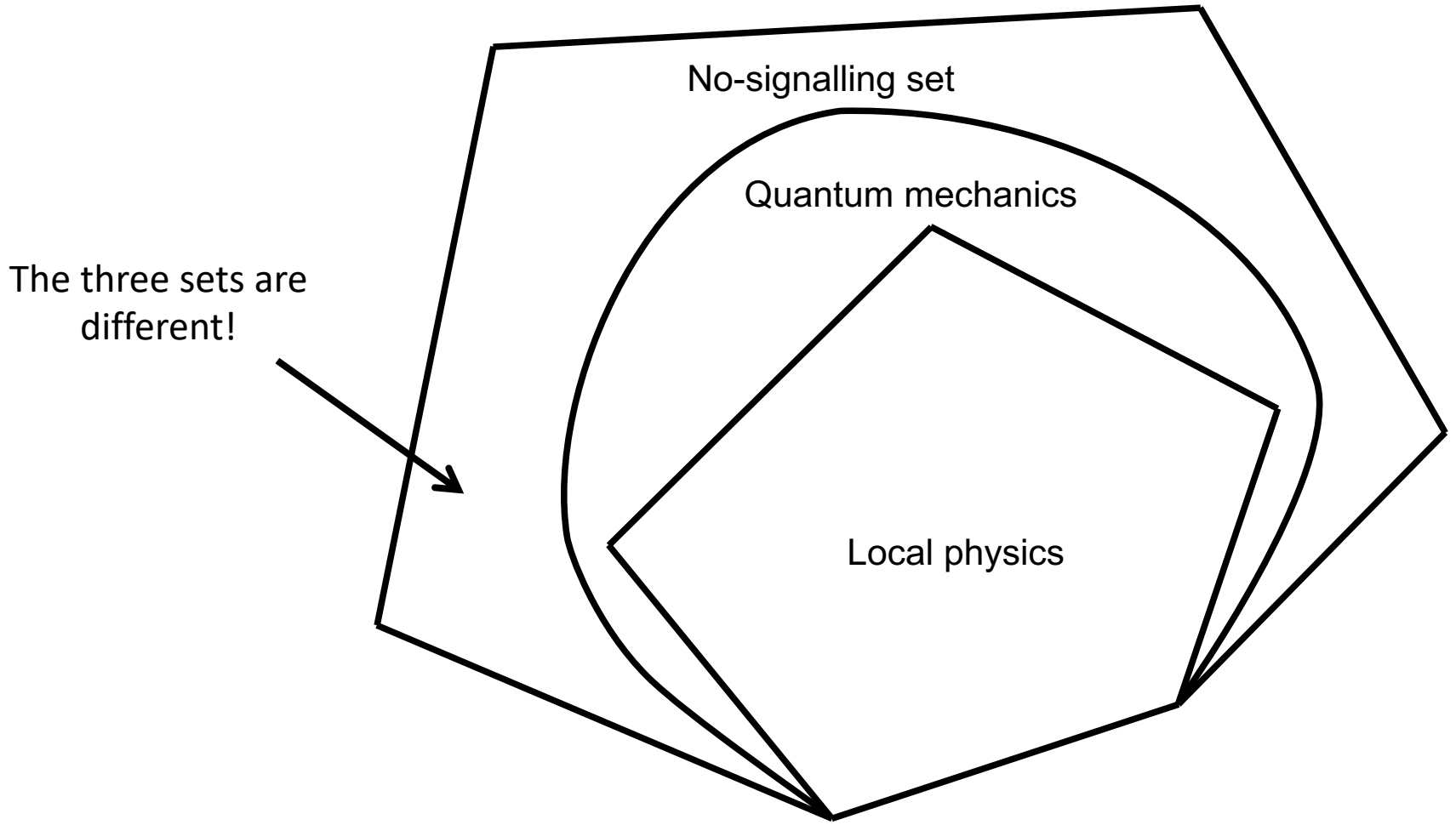
Sandu Popescu



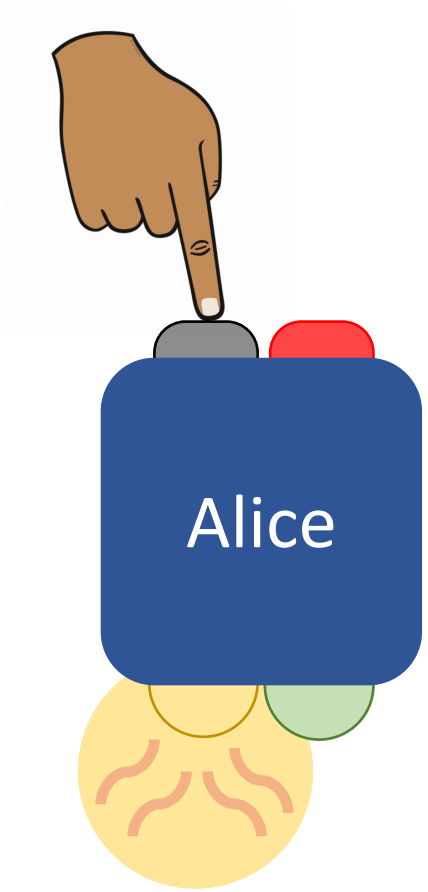
Daniel Rohrlich

S Popescu and D Rohrlich, Foundations of Physics, **24**, 379, (1994).

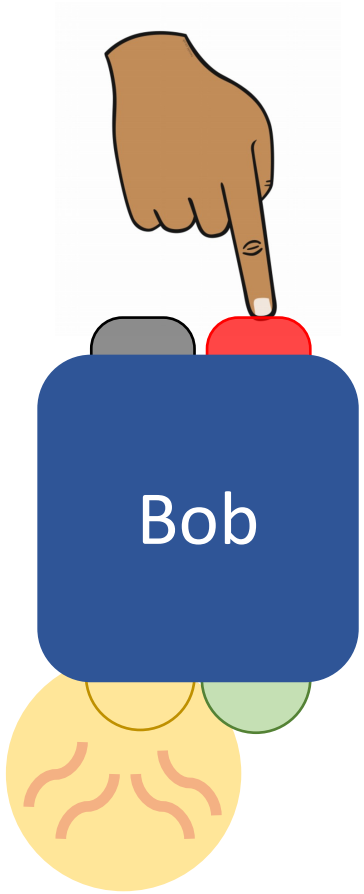
Three sets of correlations



Black box scenario



$$\{p(ab|xy)\}$$



NO SIGNALLING

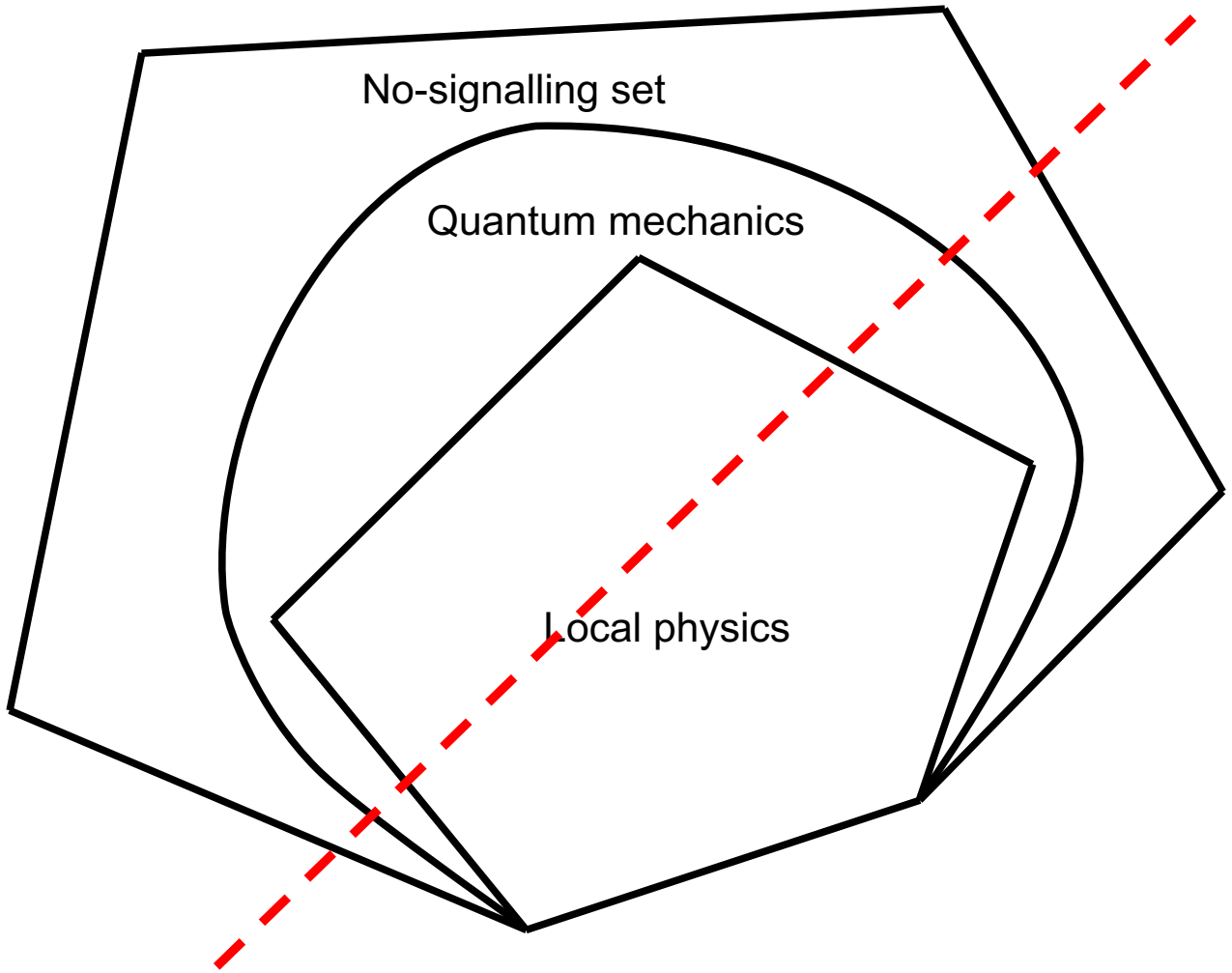
SCENARIO (2, 2, 2)
(parties, inputs, outputs)

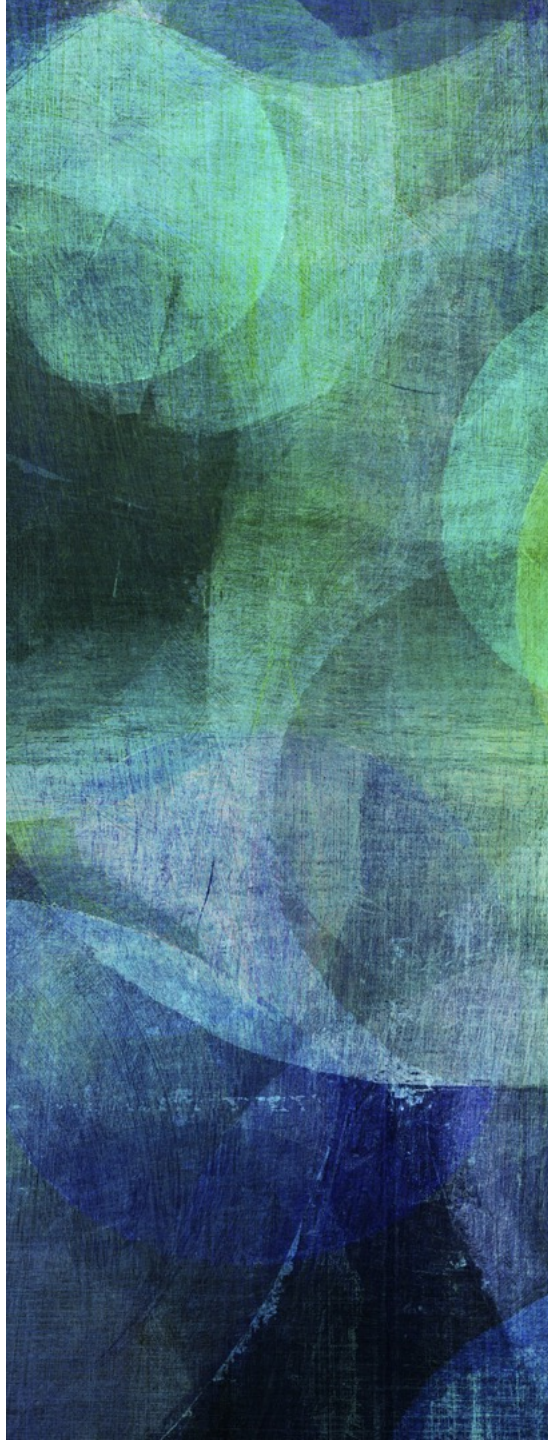
CHSH performance

CHSH ≤ 4

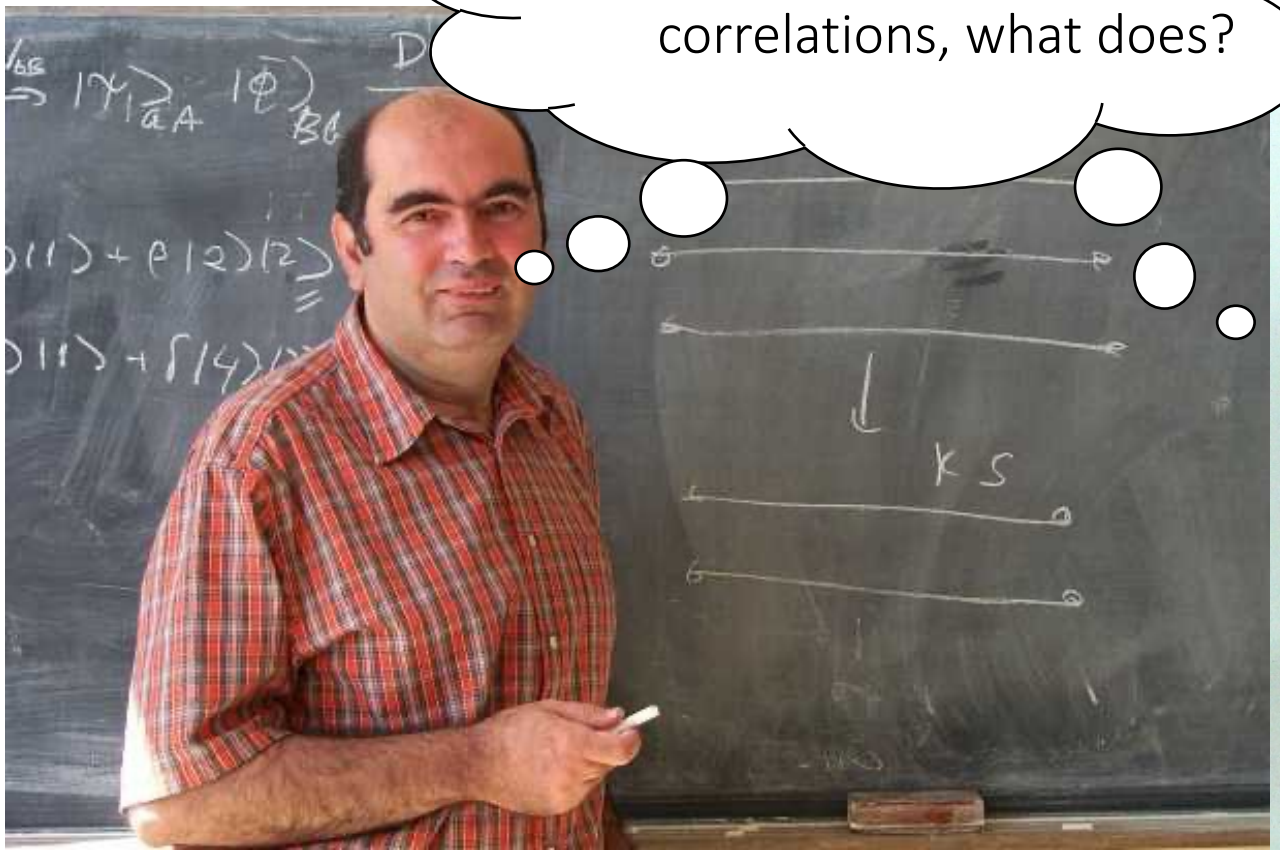
CHSH ≤ 2√2

CHSH ≤ 2





If causality does not determine quantum correlations, what does?






8
9
1

Non-trivial communication complexity

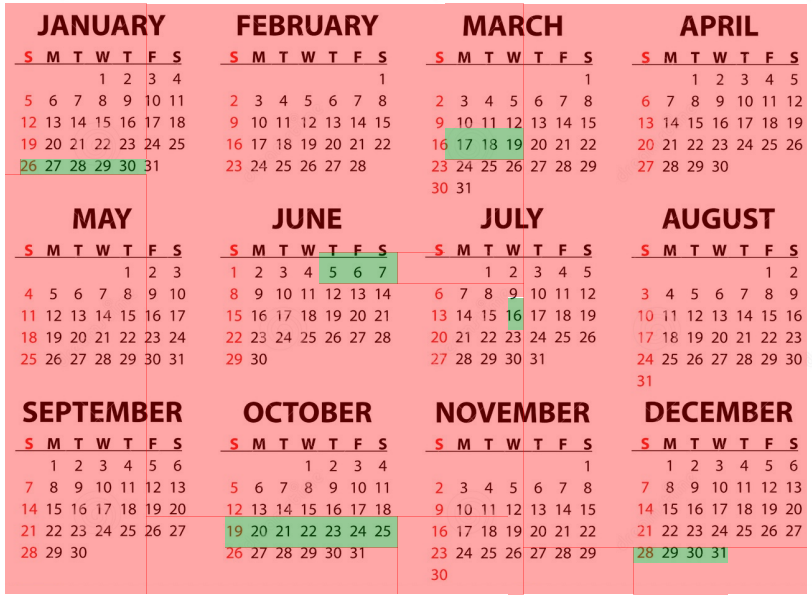
- Does quantum theory contain a special, non-trivial amount of communication complexity?
- ”Two spatially separated parties cannot compute arbitrary Boolean functions with fixed probability greater than ½ , regardless of their input size”.



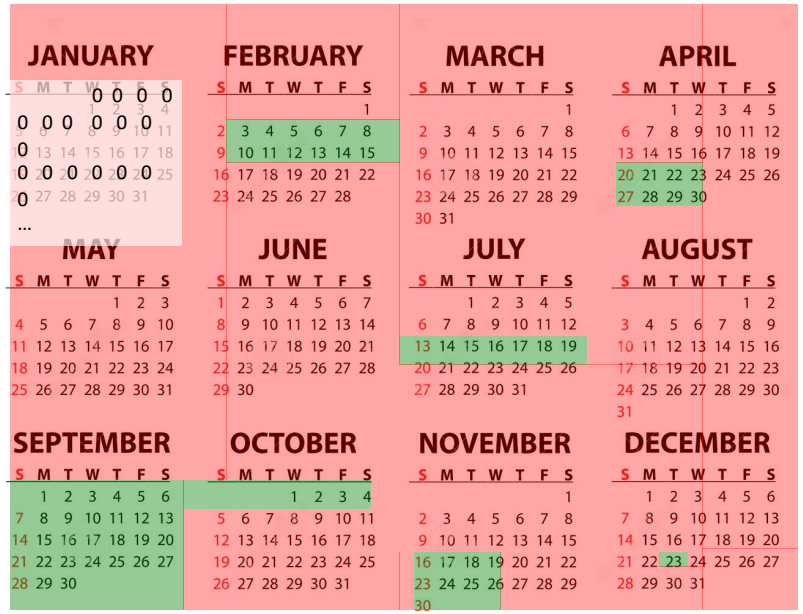
G. Brassard, H. Buhrman, N. Linden, A. A. Methot, A. Tapp and F. Unger, Phys. Rev. Lett**., 96** 250401, (2006).

The calendar problem

Alice



Bob



- **Q:** is the number of days that we are *both* free even or odd?

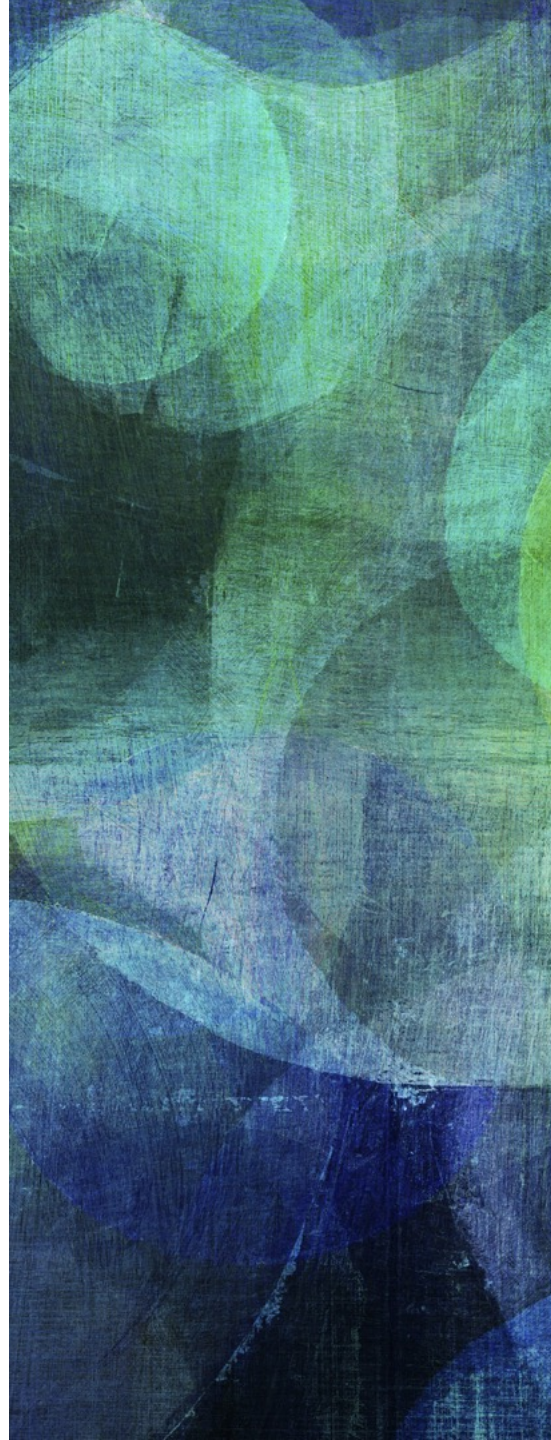




Calendar problem

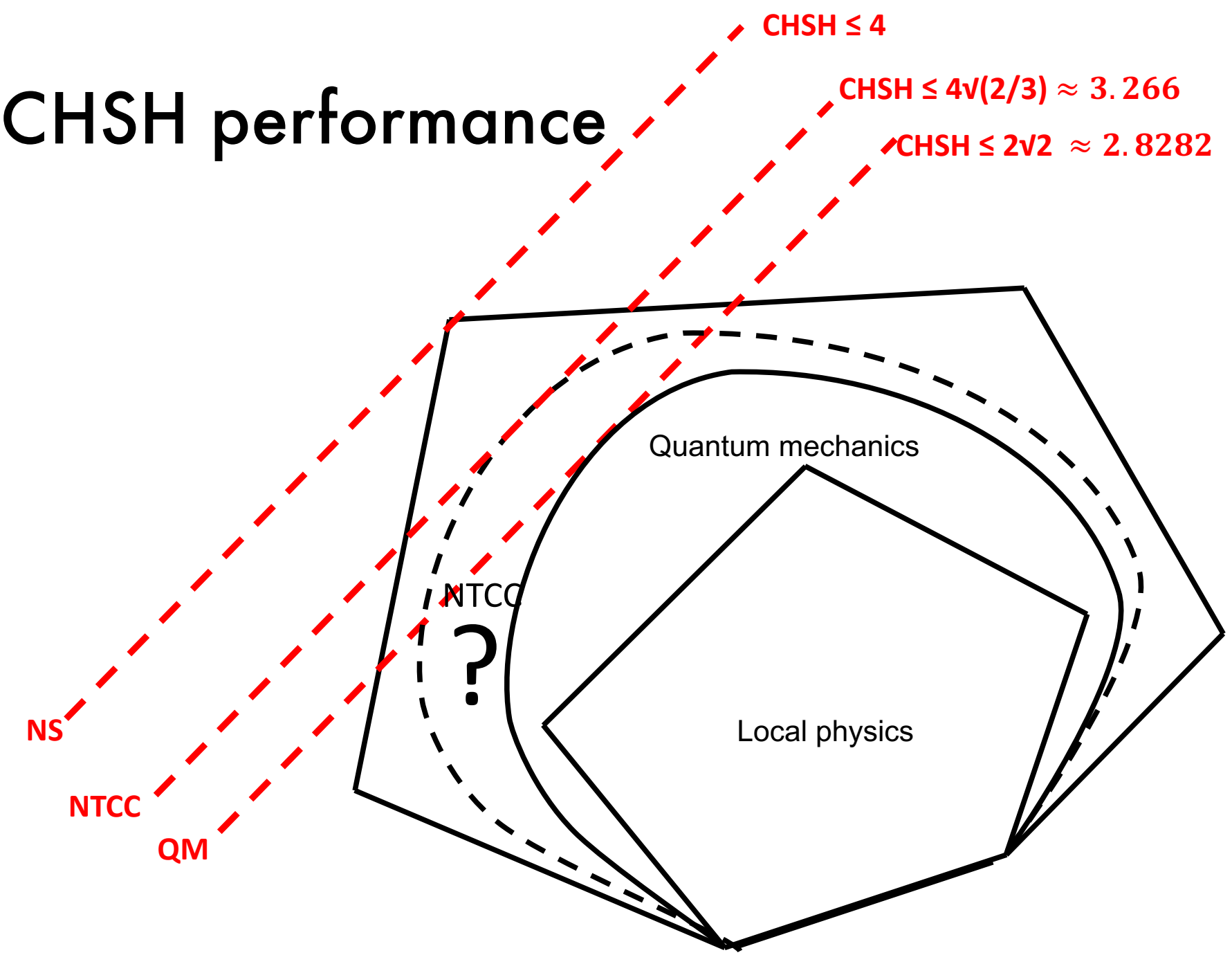
- **Classically**: Bob needs to send Alice all 365 bits to answer the question
- **Quantum**: no better for this problem
- **Other resources:** there exist resources which solve this problem in 1 bit – we call this *trivial communication complexity.*

→ Nature encodes some kind of redundancy.

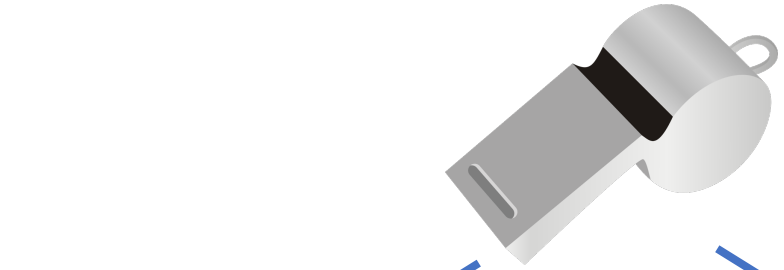


W. van Dam, "Nonlocality & communication complexity", D.Phil. Thesis, University of Oxford, Chap. 9 (2000).

CHSH performance



No Advantage for Non-local Computation



$p(\mathbf{z})$ $\mathbf{z} = (z_1, z_2, \cdots, z_n)$

$\mathbf{x} = (x_1, x_2, \cdots, x_n)$

$\mathbf{x}$

$\mathbf{y} = \mathbf{x} \oplus \mathbf{z}$

Alice

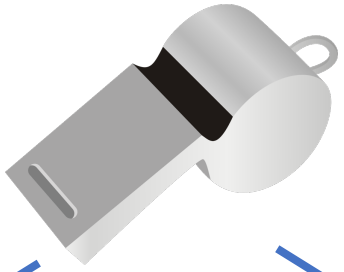
Bob

a

b

$$a \oplus b = f(\mathbf{z})$$

No Advantage for Non-local Computation



$p(\mathbf{z})$ $\mathbf{z} = (z_1, z_2, \cdots, z_n)$

$\mathbf{x} = (x_1, x_2, \cdots, x_n)$

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Alice

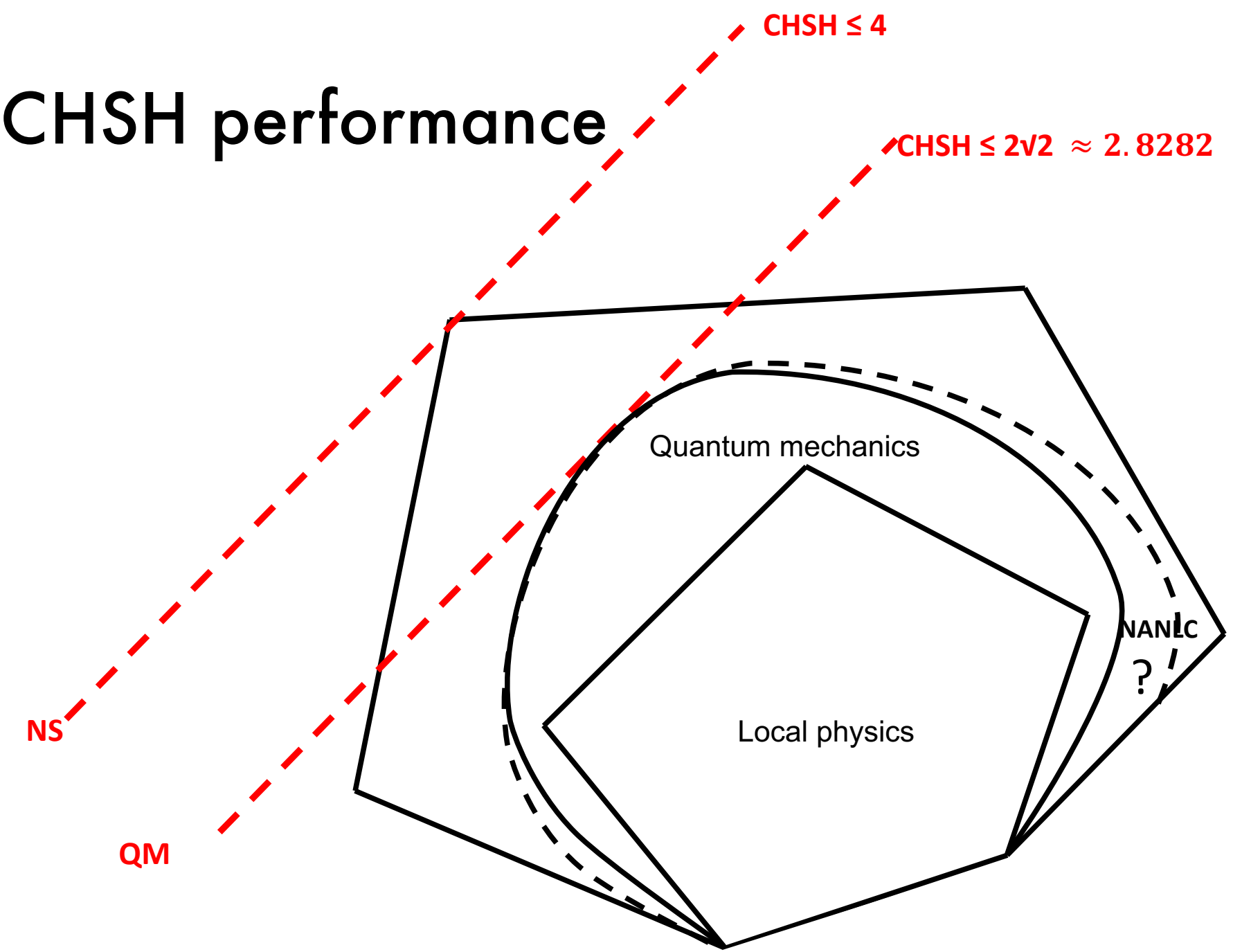
Bob

a

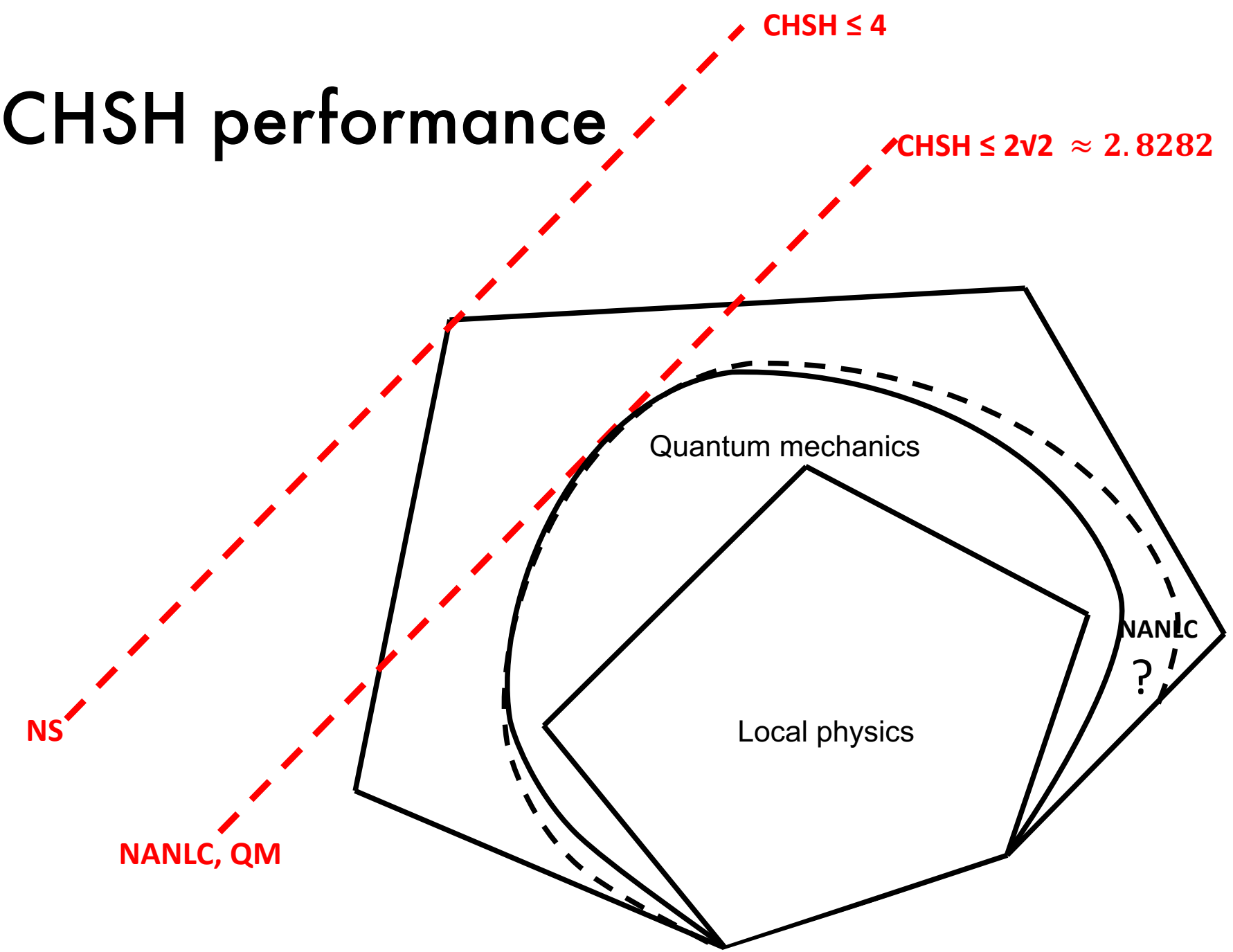
b

$$p_{\text{succ}} = \frac{1}{2^N} \sum_{\mathbf{x},\mathbf{z}} p(\mathbf{z}) p(a \oplus b = f(\mathbf{z}) | \mathbf{x}, \mathbf{z})$$

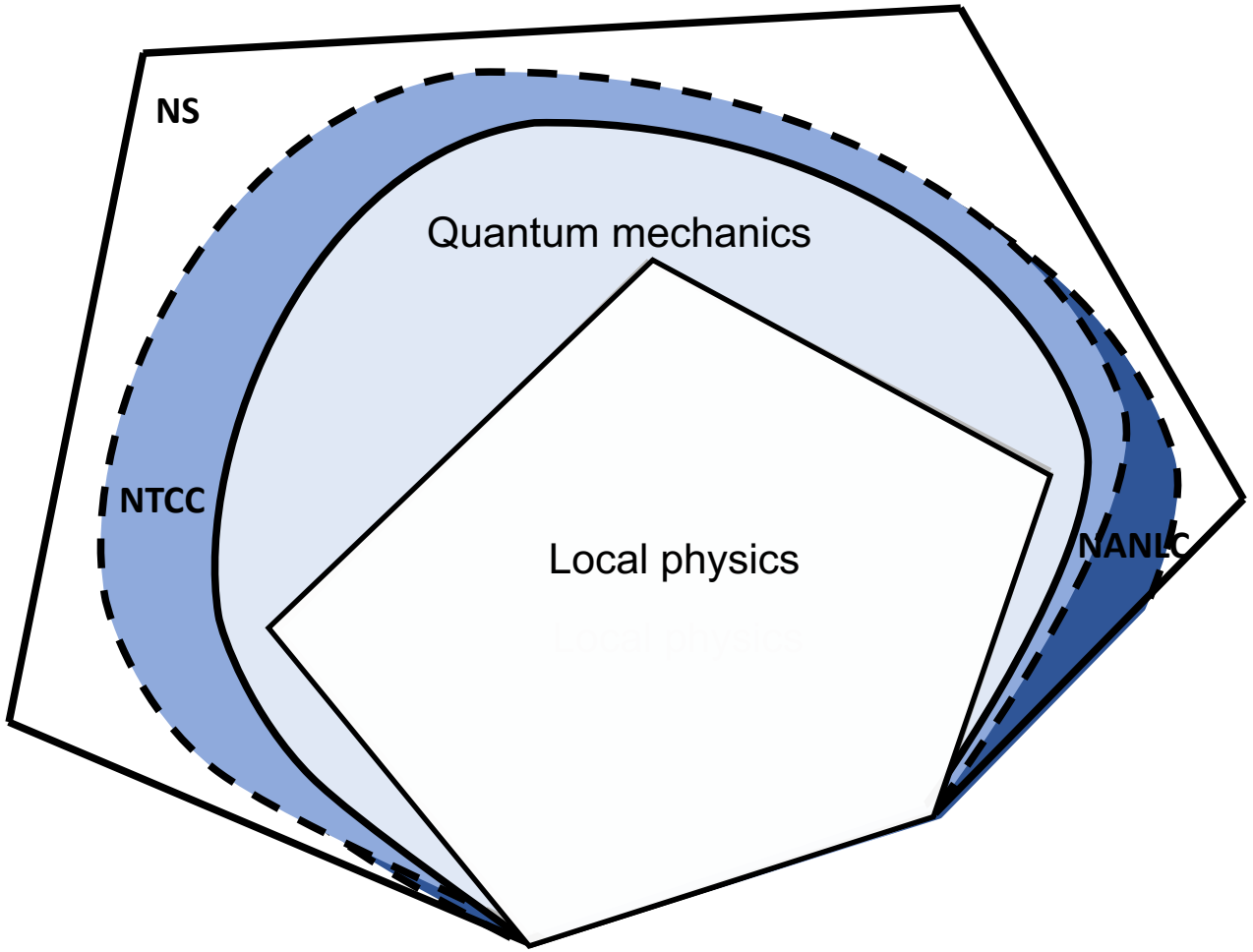
CHSH performance



CHSH performance



Catching the quantum set



Macroscopic Locality



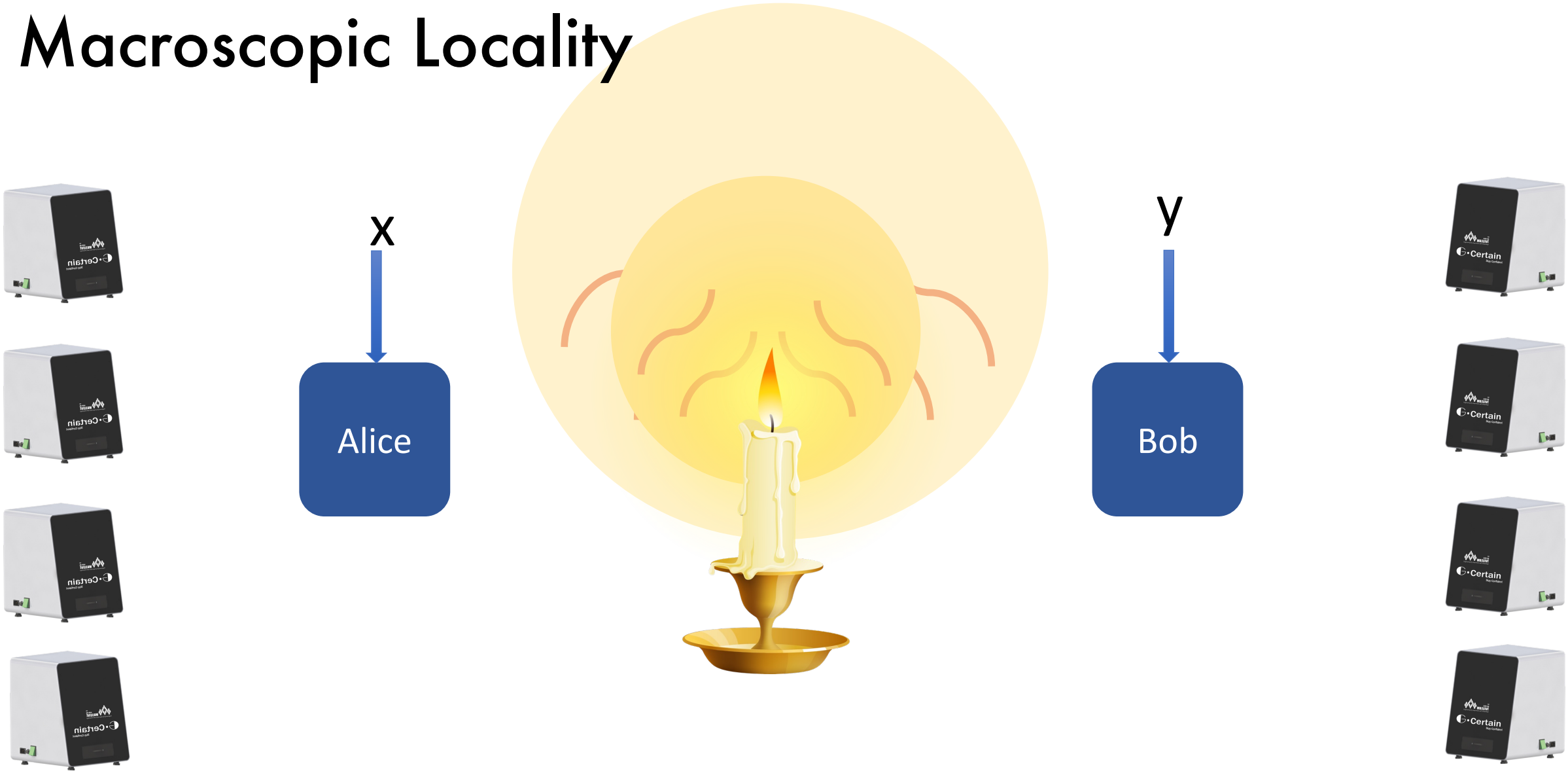
M. Navascués and H. Wunderlich, Proc. Royal Soc. A **466**, 881-890 (2009).

Macroscopic Locality



M. Navascués and H. Wunderlich, Proc. Royal Soc. A **466**, 881-890 (2009).

Macroscopic Locality



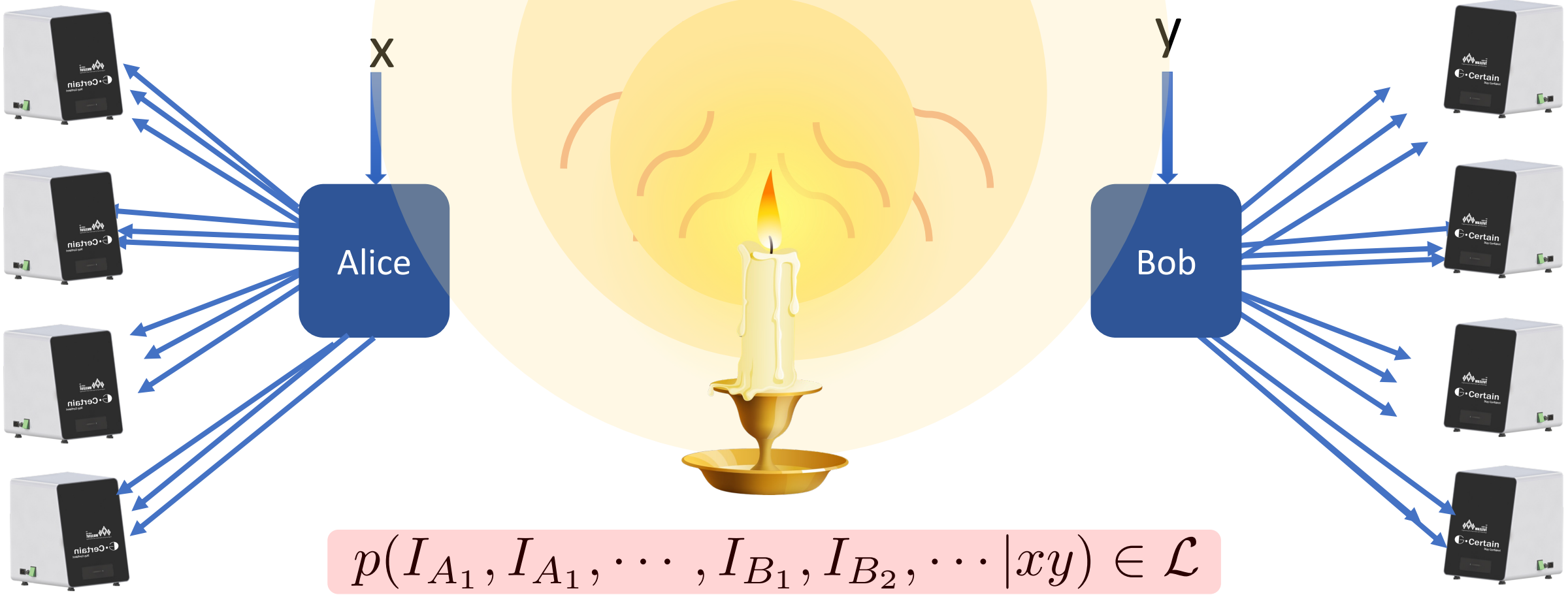
M. Navascués and H. Wunderlich, Proc. Royal Soc. A **466**, 881-890 (2009).

Macroscopic Locality



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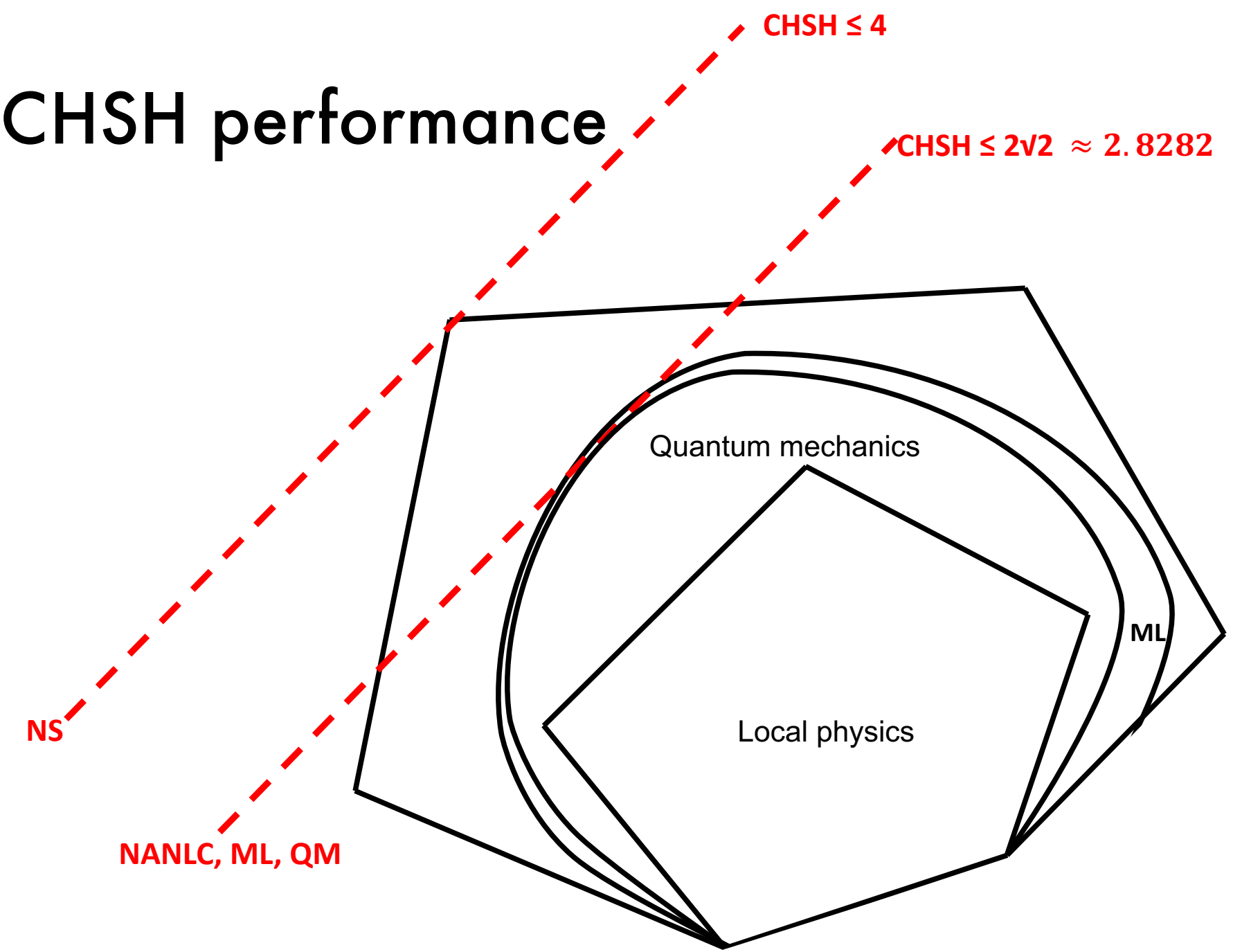
Macroscopic Locality



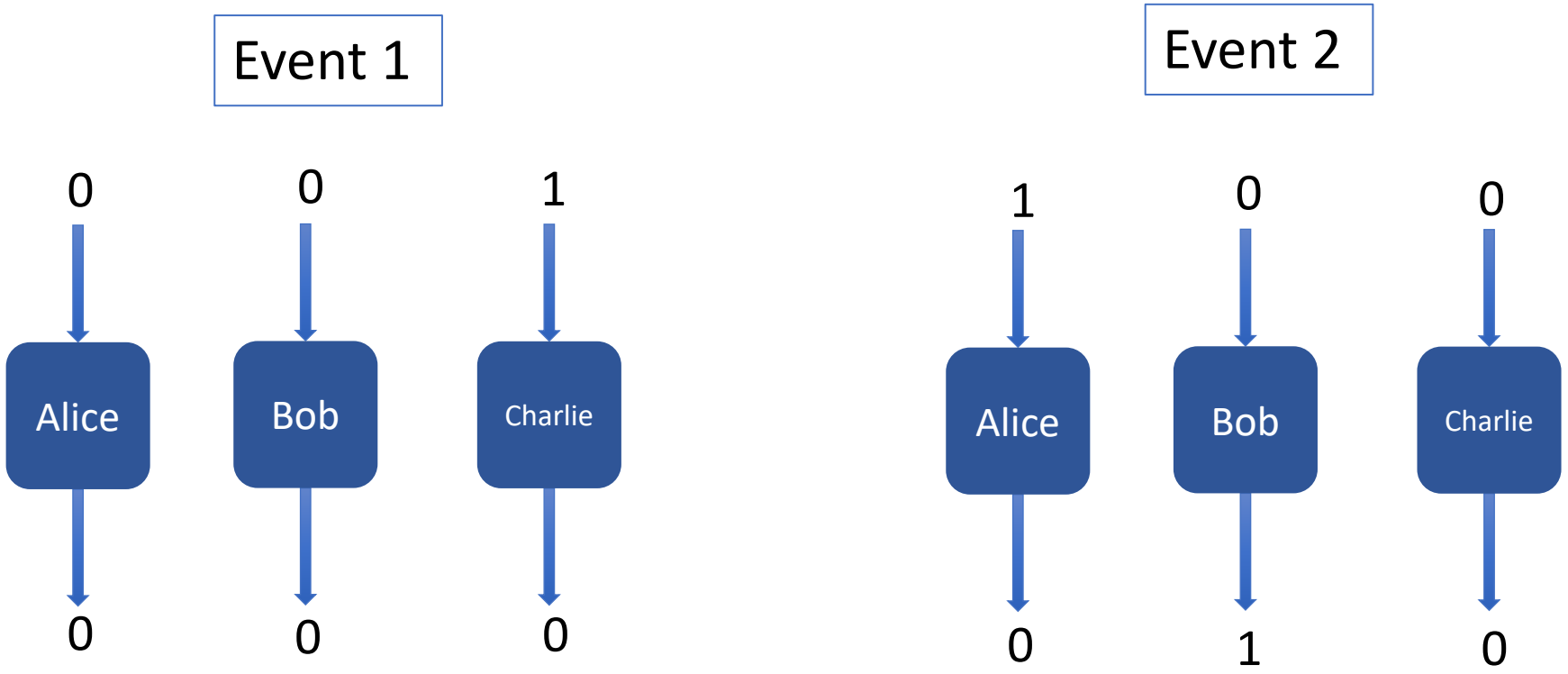
$$p(I_{A_1}, I_{A_1}, \cdots, I_{B_1}, I_{B_2}, \cdots | xy) \in \mathcal{L}$$

M. Navascués and H. Wunderlich, Proc. Royal Soc. A **466**, 881-890 (2009).

CHSH performance



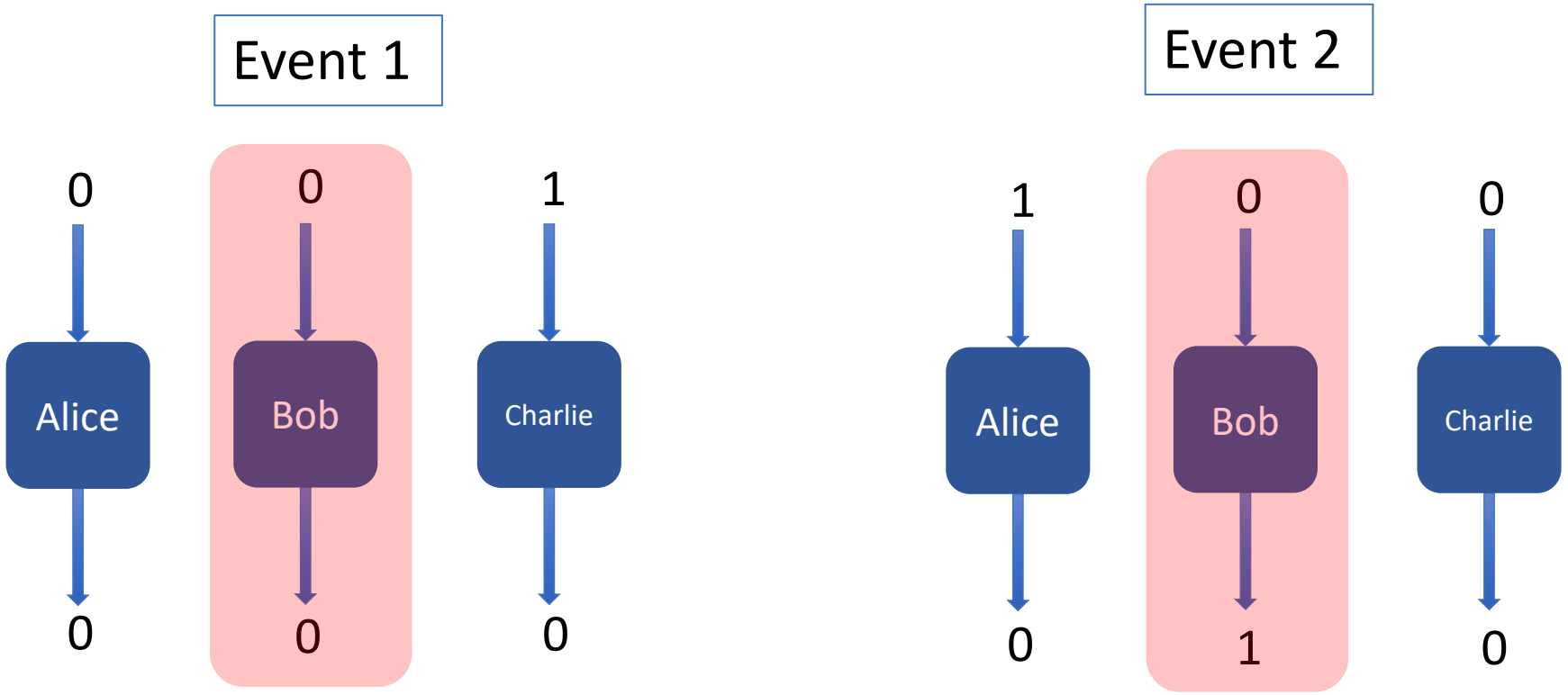
Local orthogonality



Events are pairwise locally orthogonal, if there exists a party that on the *same* input produces *different* outputs.

T. Fritz, A. B. Sainz, R. Augusiak, J. B. Brask, R. Chaves, A. Leverrier and A. Acín, Nature Communications 4, 2263 (2013) . A. Cabello, arXiv:1212.1756 (2012)

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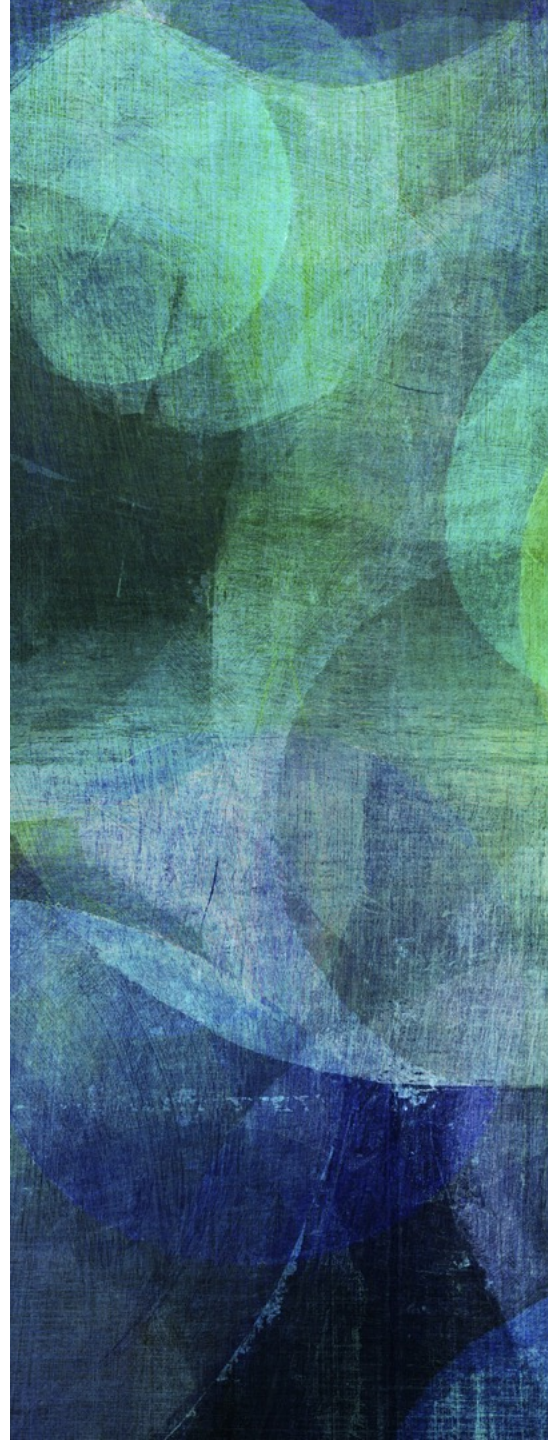
T. Fritz, A. B. Sainz, R. Augusiak, J. B. Brask, R. Chaves, A. Leverrier and A. Acín, Nature Communications 4, 2263 (2013) . A. Cabello, arXiv:1212.1756 (2012)

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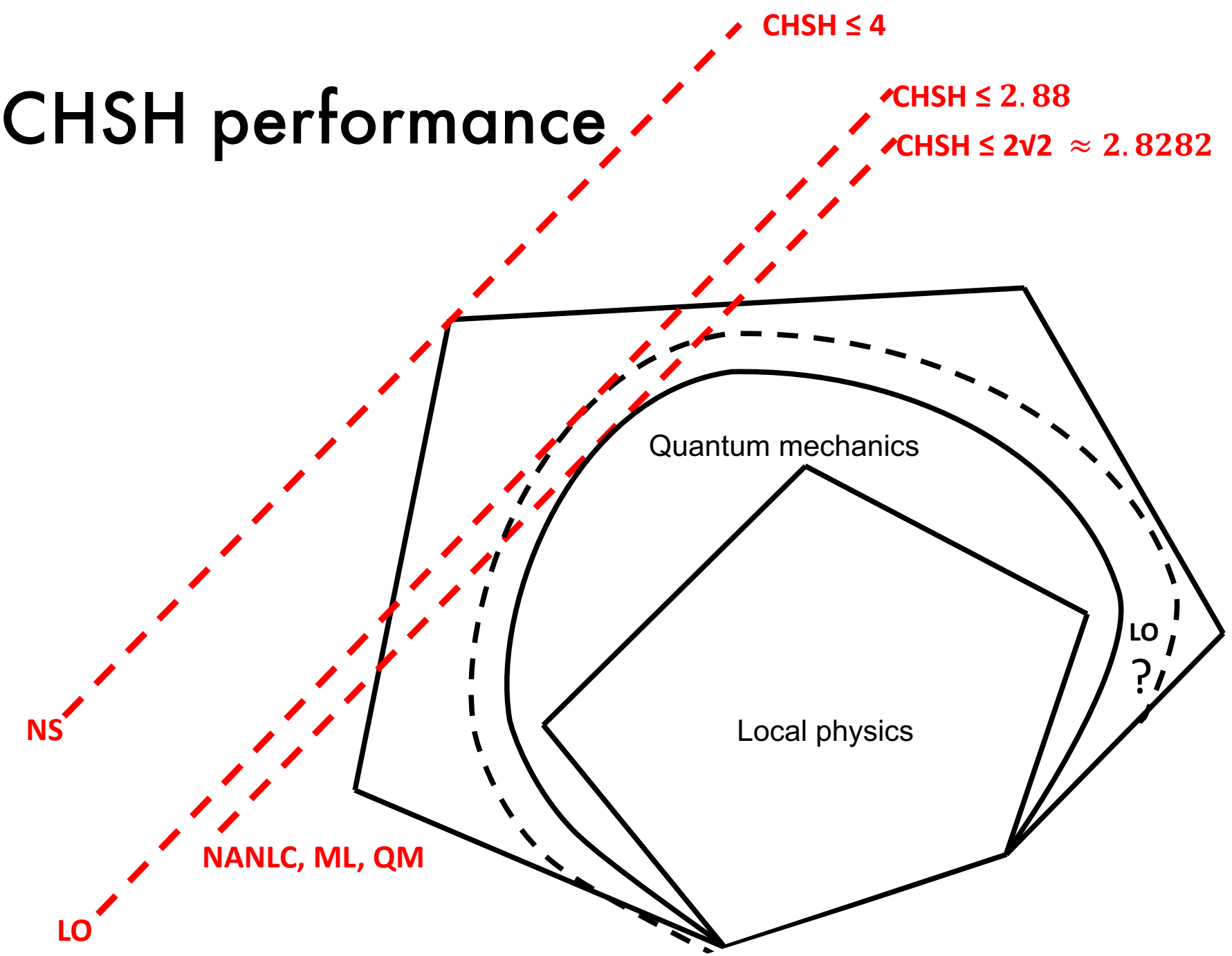
$$LO \Longrightarrow \sum_{e \in E} P(e) \leq 1$$

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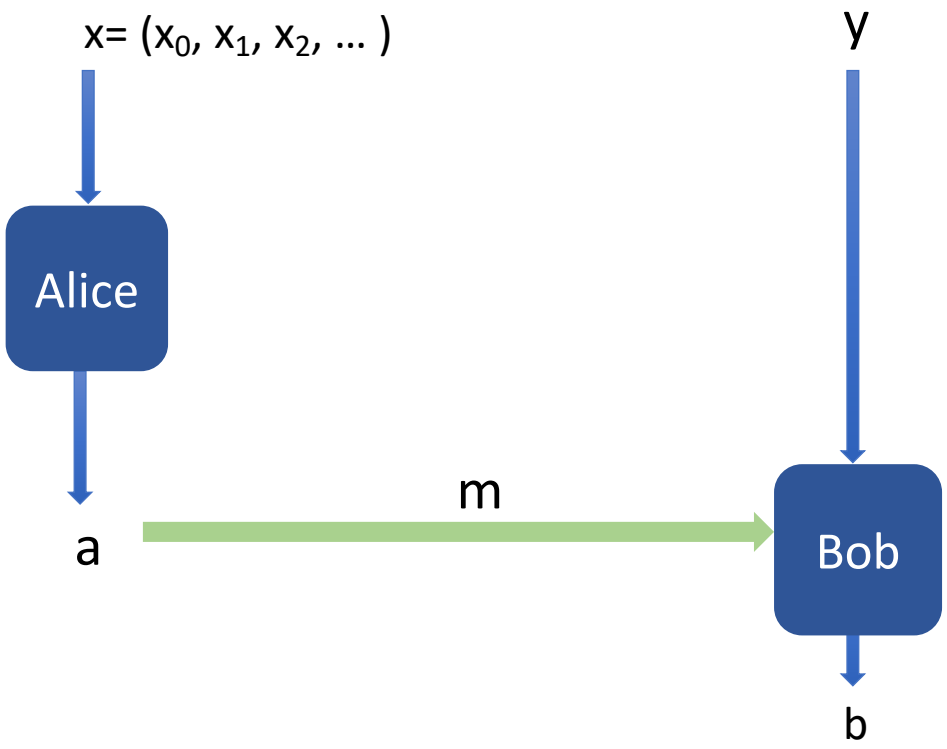


CHSH performance



Information Causality

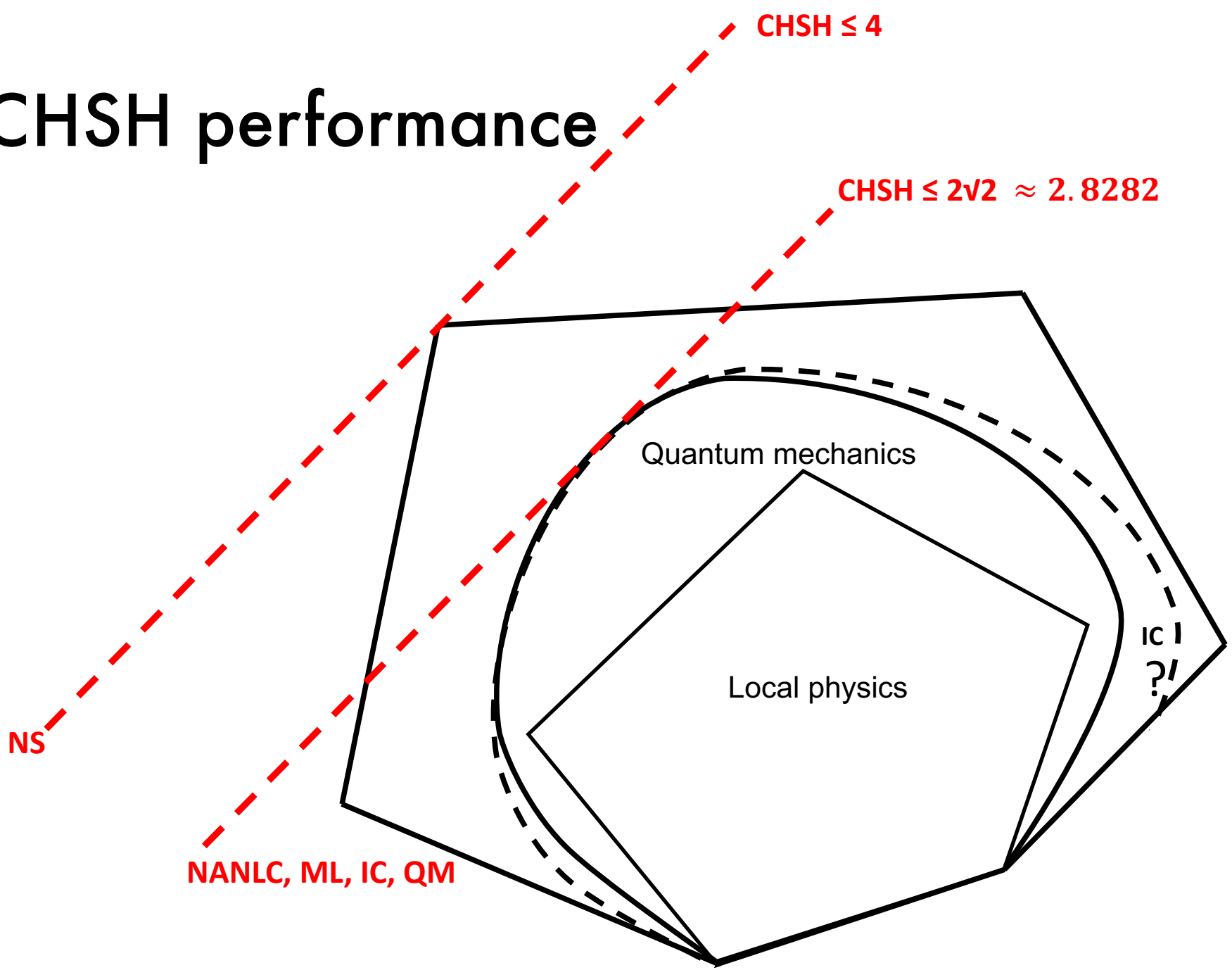
- The amount of information available to Bob about Alice's input cannot exceed the message she sends.

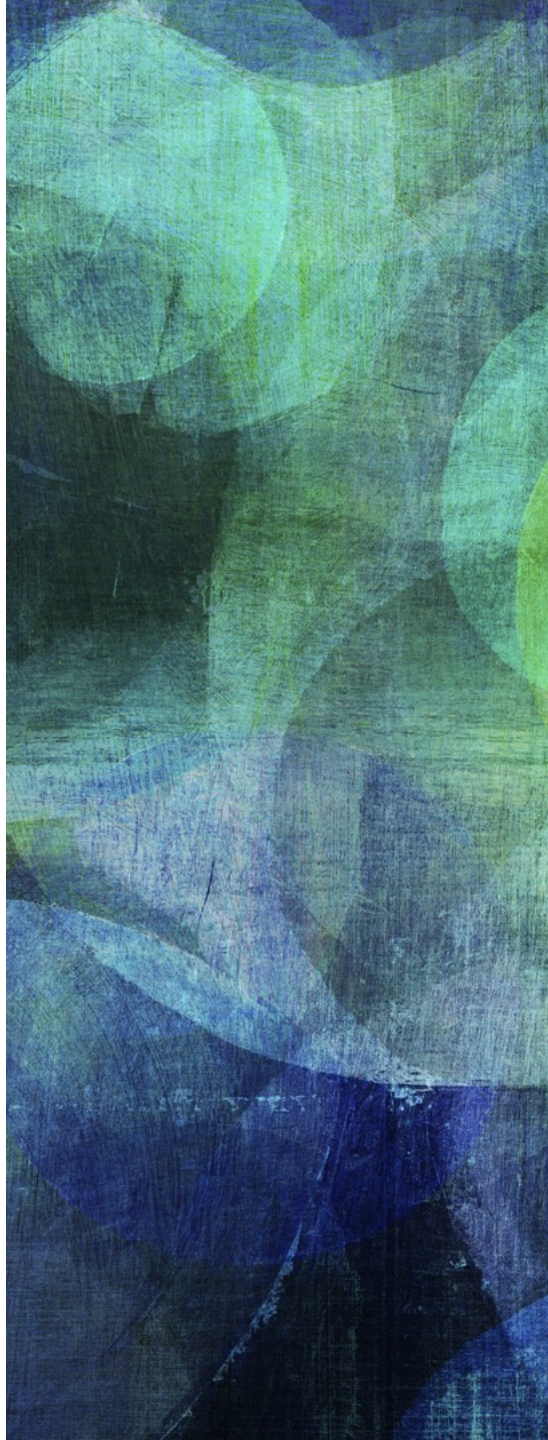


Goal: $b = x_y$

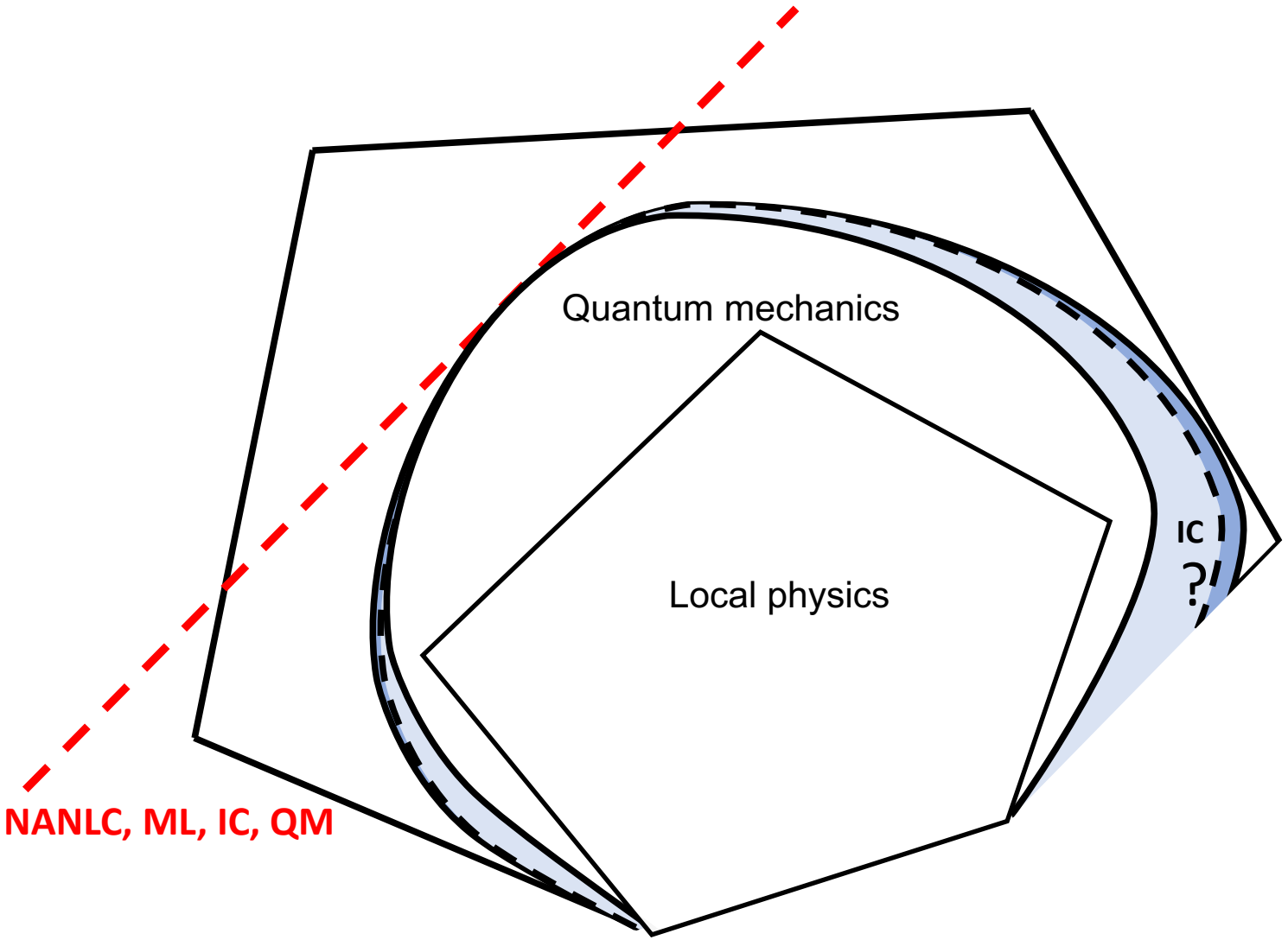
M. Pawlowski, T. Paterek, D. Kaszlikowski, V. Scarani, A. Winter, and M. Zukowski, Nature **461**, 1101 (2009).

CHSH performance



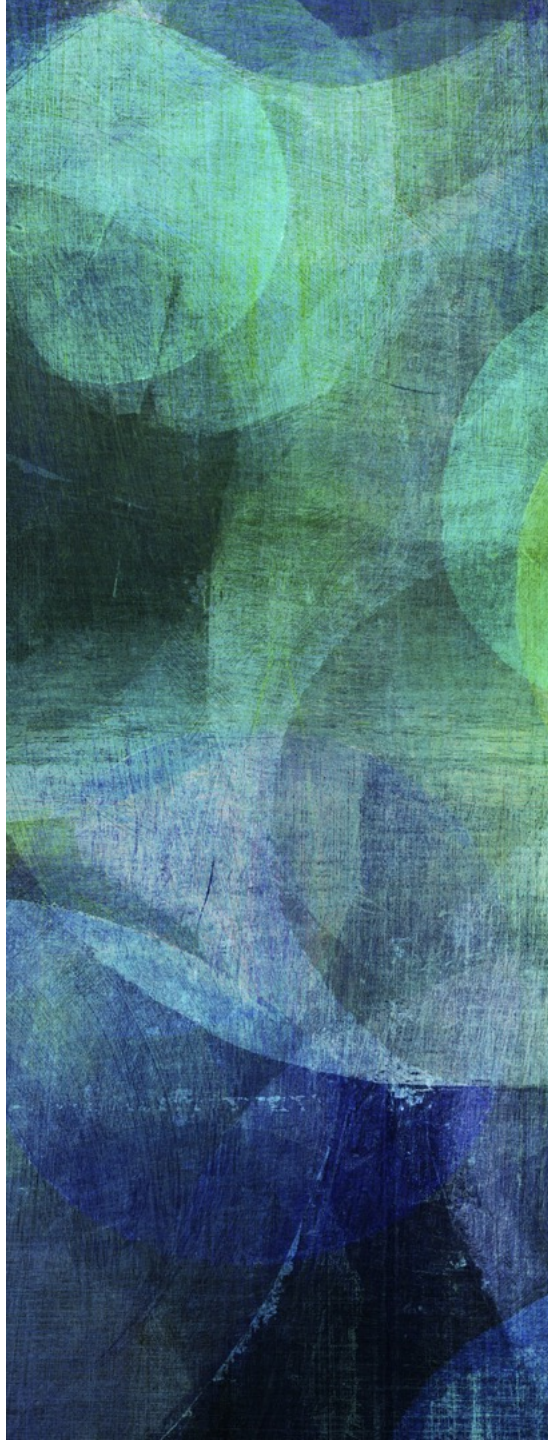


Some ML correlations violate IC

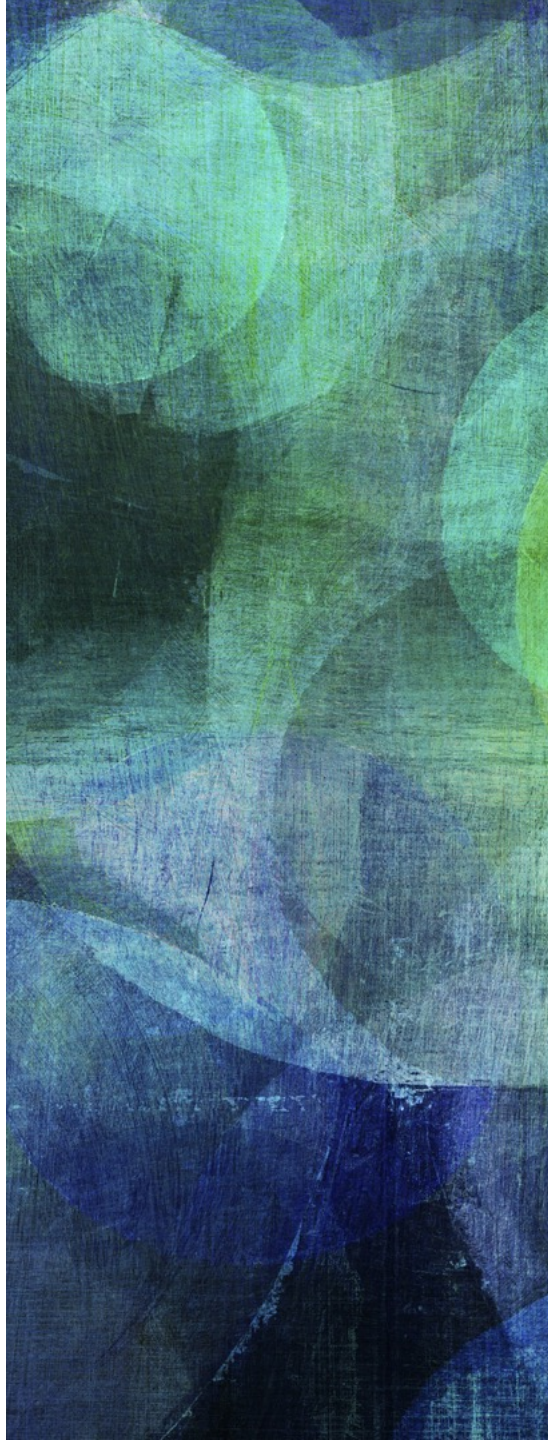


D Cavalcanti, A Salles & V Scarani, Nature Communications **1**, 136 (2010)

Are these principles enough to single out the quantum set?



Can one devise a theory that satisfies all these principles, but that is not quantum mechanics?



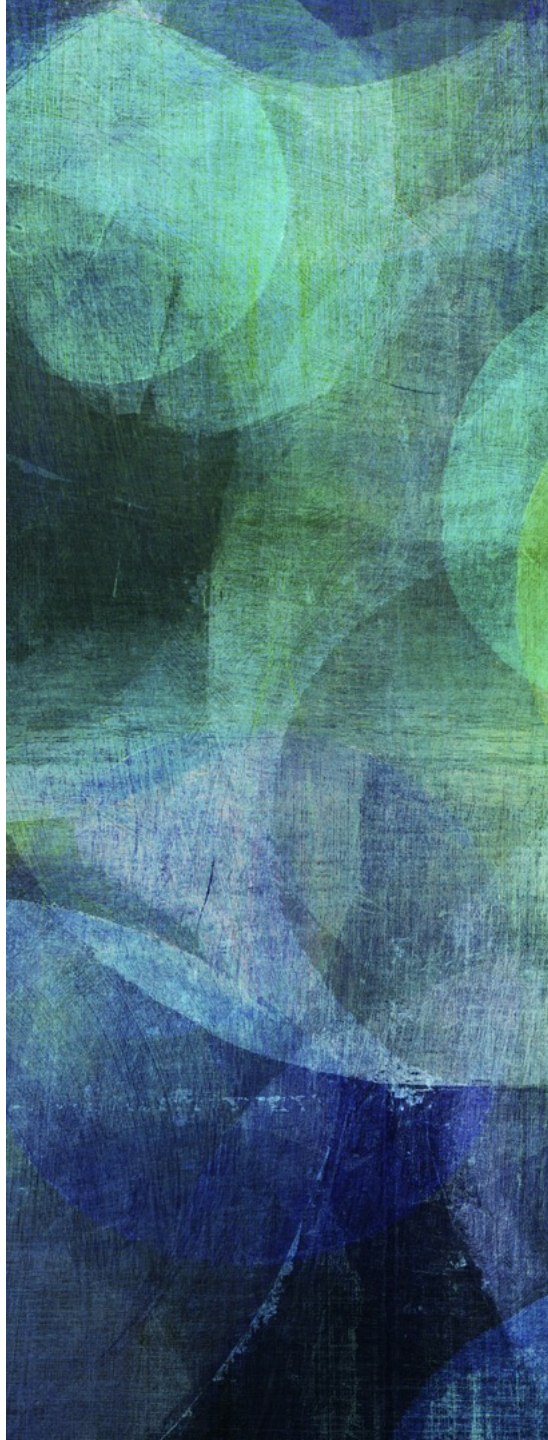
Almost quantum correlations



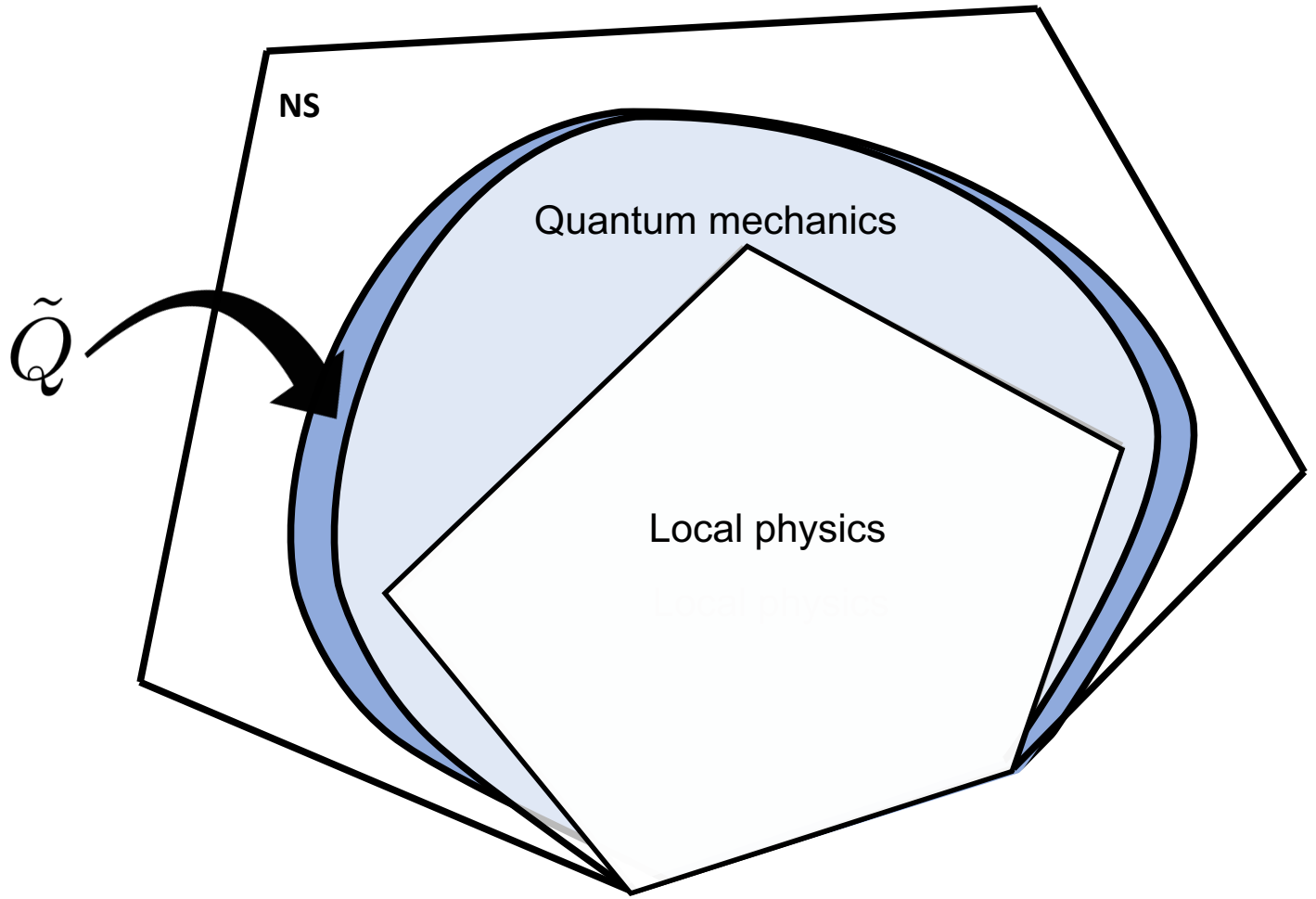
A difference of definitions

	$\mathcal{Q}$: **Quantum**	$\tilde{\mathcal{Q}}$: **Almost Quantum**
Conditional Probabilities	$p(a_1, a_2, \ldots, a_n \vert x_1, x_2, \ldots, x_n) = \langle\psi\vert \prod_{j=1}^{n} E_j^{a_j,x_j} \vert\psi\rangle$	
States $\vert\Psi\rangle$	Normalised vector in a Hilbert space $\mathcal{H}$	
Measurements	$E_j^{a_j,x_j}$ are projectors acting on $\mathcal{H}$. Define the measurements by each party as $E_j^{a'_j,x_j} E_j^{a_j,x_j} = \delta_{a'_j}^{a_j} E_j^{a_j,x_j}$ and $\sum_{a_j} E_j^{a_j,x_j} = \mathbb{I}$	
Commutation	Any two measurement operators of two different parties commute $[E_j^{a_j,x_j}, E_{j'}^{a_{j'},x_{j'}}] = 0$	Projectors commute on a state $E_1^{a_1,x_1} \ldots E_n^{a_n,x_n} \vert\psi\rangle = E_{\pi(1)}^{a_{\pi(1)},x_{\pi(1)}} \ldots E_{\pi(n)}^{a_{\pi(n)},x_{\pi(n)}} \vert\psi\rangle$ for arbitrary permutation π of the n parties

Miguel Navascués, YG, Matty J. Hoban & Antonio Acín, Nature Communications **6**, 6288 (2015)



Almost quantum

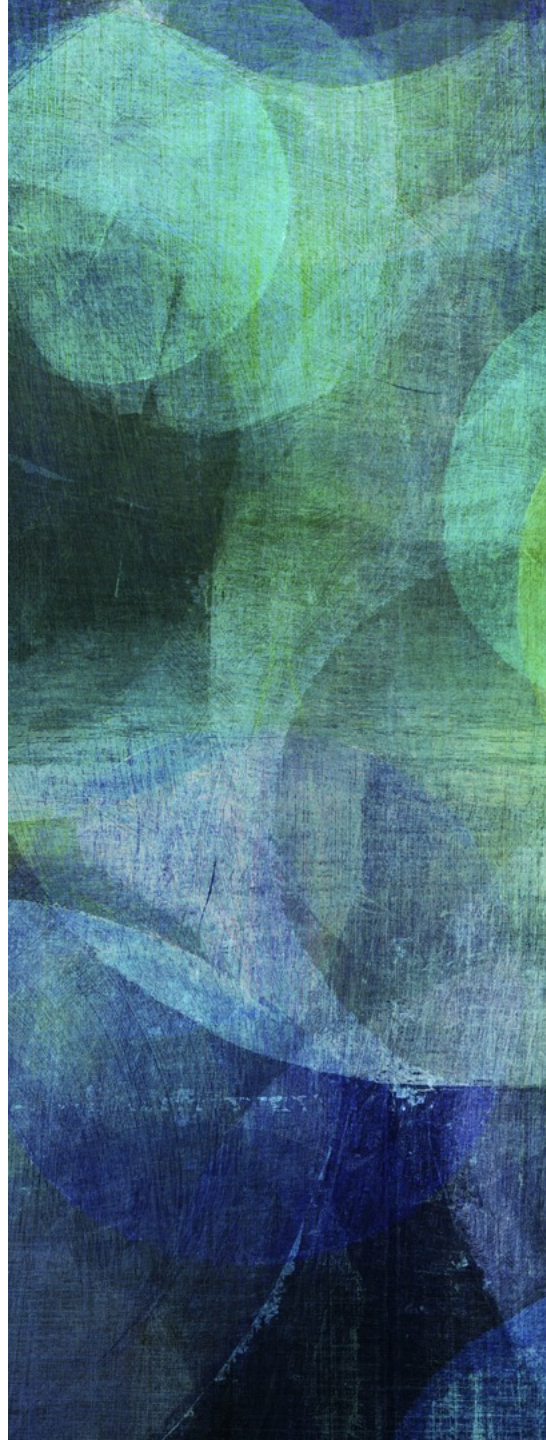


Almost quantum: properties

- $\tilde{Q}$ is closed under post-selection, distribution and wirings

  N. Linden, S. Popescu, P. Skrzypczyk, T. Vertesi, Phys. Rev. A **80**, 062107 (2009).

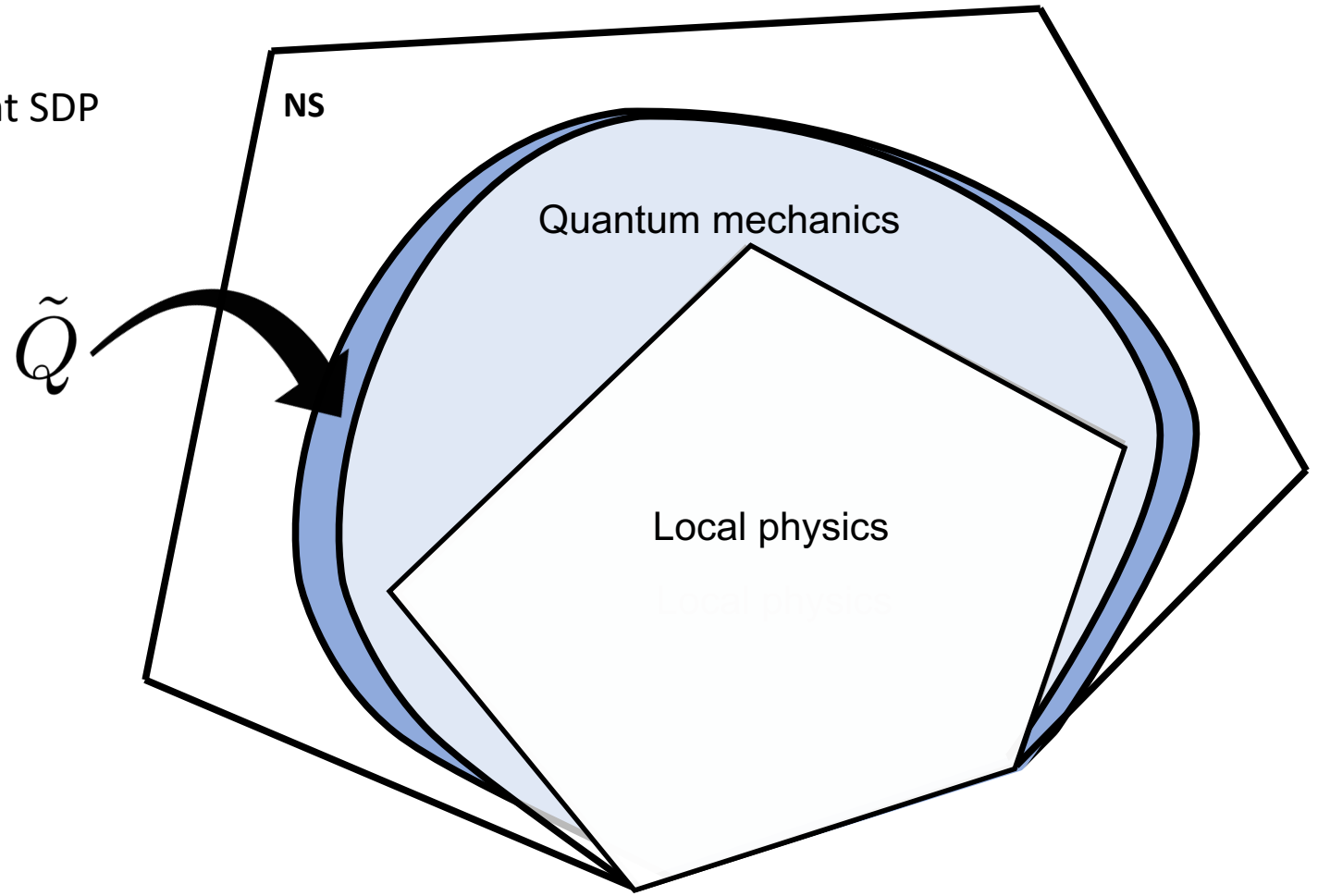
- ☑ Non-trivial communication complexity (NTCC)
- ☑ No Advantage for Non-local Communication (NANLC)
- ☑ Macroscopic locality (ML)
- ☑ Local Orthogonality (LO)
- ☑ Information Causality (IC)



Miguel Navascués, YG, Matty J. Hoban & Antonio Acín, Nature Communications **6**, 6288 (2015)

Almost quantum

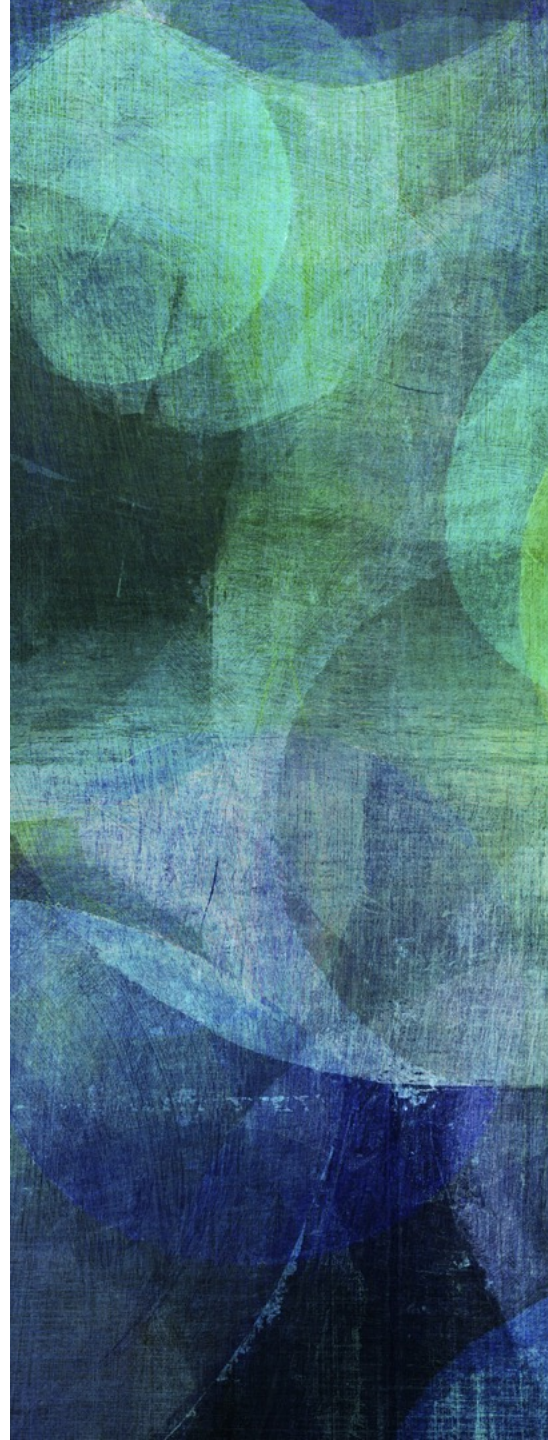
Admits an efficient SDP characterisation !



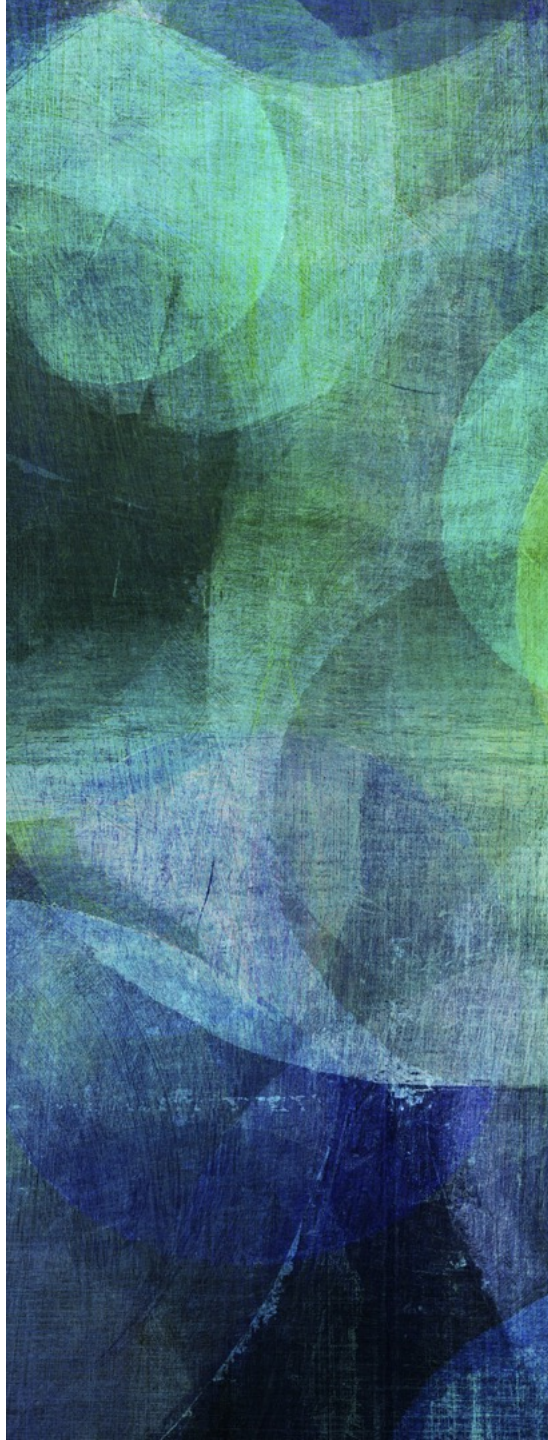
M. Navascués, S. Pironio and A. Acín, New J. Phys. 10 073013 (2008).

Almost quantum

$$\begin{pmatrix}
1 & \frac{9}{20} & \frac{2}{11} & \frac{2}{11} & \frac{9}{20} & \frac{22}{125} & \frac{\sqrt{2}}{9} & \frac{37}{700} & \frac{22}{125} \\
\frac{9}{20} & \frac{9}{20} & \frac{17}{155} & \frac{22}{125} & \frac{37}{700} & \frac{22}{125} & \frac{\sqrt{33}}{40} & \frac{37}{700} & \frac{\sqrt{71}}{100} \\
\frac{2}{11} & \frac{17}{155} & \frac{2}{11} & \frac{\sqrt{2}}{9} & \frac{22}{125} & \frac{\sqrt{33}}{40} & \frac{\sqrt{2}}{9} & \frac{\sqrt{71}}{100} & \frac{22}{125} \\
\frac{2}{11} & \frac{22}{125} & \frac{\sqrt{2}}{9} & \frac{2}{11} & \frac{17}{155} & \frac{22}{125} & \frac{\sqrt{2}}{9} & \frac{\sqrt{71}}{100} & \frac{\sqrt{33}}{40} \\
\frac{9}{20} & \frac{37}{700} & \frac{22}{125} & \frac{17}{155} & \frac{9}{20} & \frac{\sqrt{71}}{100} & \frac{\sqrt{33}}{40} & \frac{37}{700} & \frac{22}{125} \\
\frac{22}{125} & \frac{22}{125} & \frac{\sqrt{33}}{40} & \frac{22}{125} & \frac{\sqrt{71}}{100} & \frac{22}{125} & \frac{\sqrt{33}}{40} & \frac{\sqrt{71}}{100} & \frac{21}{158} \\
\frac{\sqrt{2}}{9} & \frac{\sqrt{33}}{40} & \frac{\sqrt{2}}{9} & \frac{\sqrt{2}}{9} & \frac{\sqrt{33}}{40} & \frac{\sqrt{33}}{40} & \frac{\sqrt{2}}{9} & \frac{4}{53} & \frac{\sqrt{33}}{40} \\
\frac{37}{700} & \frac{37}{700} & \frac{\sqrt{71}}{100} & \frac{\sqrt{71}}{100} & \frac{37}{700} & \frac{\sqrt{71}}{100} & \frac{4}{53} & \frac{37}{700} & \frac{\sqrt{71}}{100} \\
\frac{22}{125} & \frac{\sqrt{71}}{100} & \frac{22}{125} & \frac{\sqrt{33}}{40} & \frac{22}{125} & \frac{21}{158} & \frac{\sqrt{33}}{40} & \frac{\sqrt{71}}{100} & \frac{22}{125}
\end{pmatrix}$$



Are almost quantum correlations a consistent alternative theory?




CAN'T FAIL CAFE
OPEN EVE

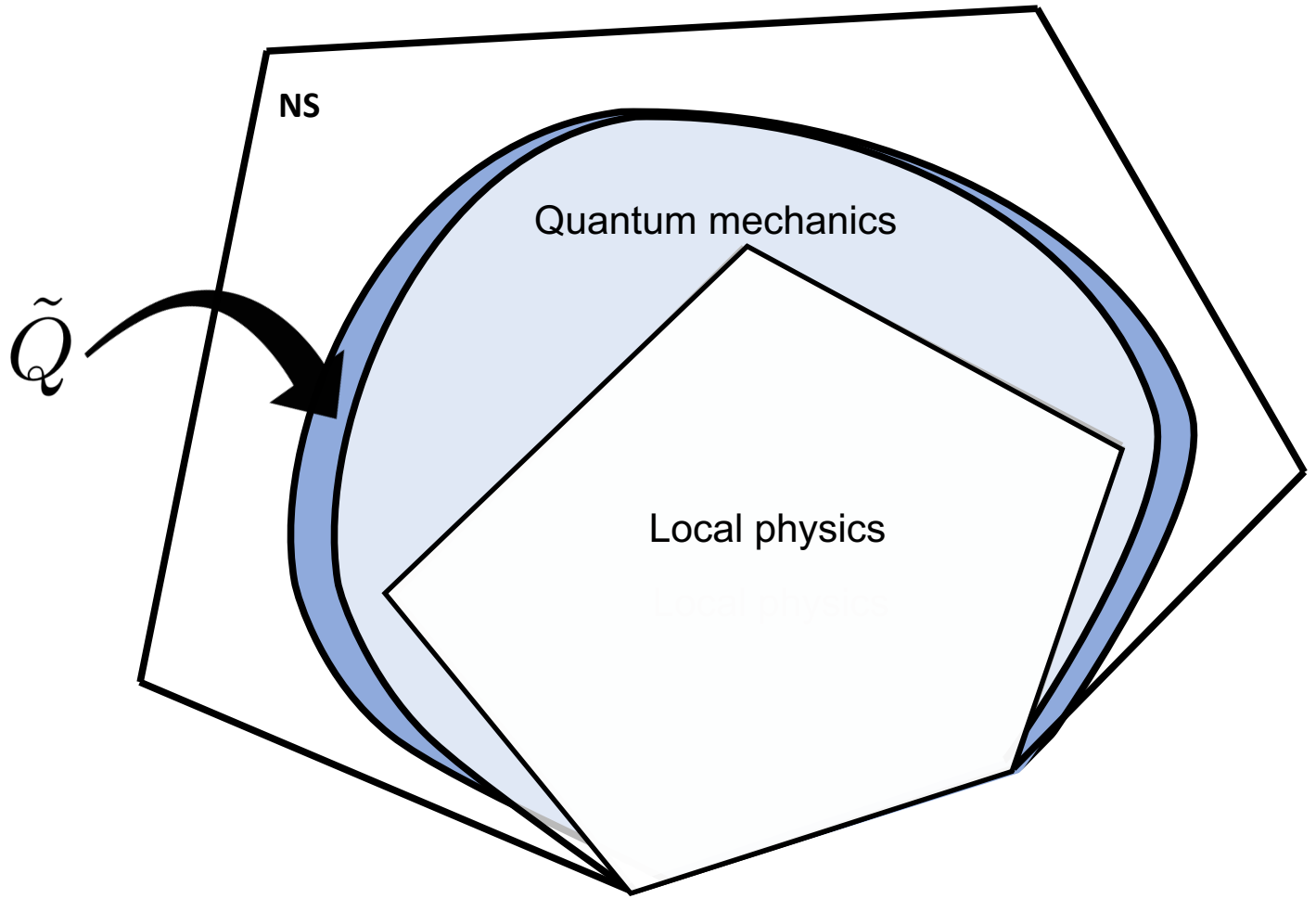
Are almost quantum correlations a consistent alternative theory?

- No! A generalised probabilistic theory which satisfies the no-restriction hypothesis is not able to reproduce the set of almost quantum correlations.
- **No-restriction hypothesis:** any mathematically well-defined measurement in the theory should be physically allowed.
- Implies that any theory whose correlations are exactly (or v. close to) the almost quantum correlations *necessarily* requires a rule limiting the possible measurements.



Ana Belén Sainz, YG, Antonio Acín,and Miguel Navascués. Phys. Rev. Lett. 120, 200402 (2018).

Almost quantum



Is QT special because it admits complex numbers?

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"What is unpleasant here, and indeed directly to be objected to, is the use of complex numbers. Ψ is surely fundamentally a real function."

Letter from Schrödinger to Lorentz. June 6th, 1926.

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"What is unpleasant here, and indeed directly to be objected to, is the use of complex numbers. Ψ is surely fundamentally a real function."

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Article | Open Access | Published: 15 December 2021

Quantum theory based on real numbers can be experimentally falsified

Marc-Olivier Renou, David Trillo, Mirjam Weilenmann, Thinh P. Le, Armin Tavakoli, Nicolas Gisin, Antonio Acín & Miguel Navascués

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Testing Real Quantum Theory in an Optical Quantum Network

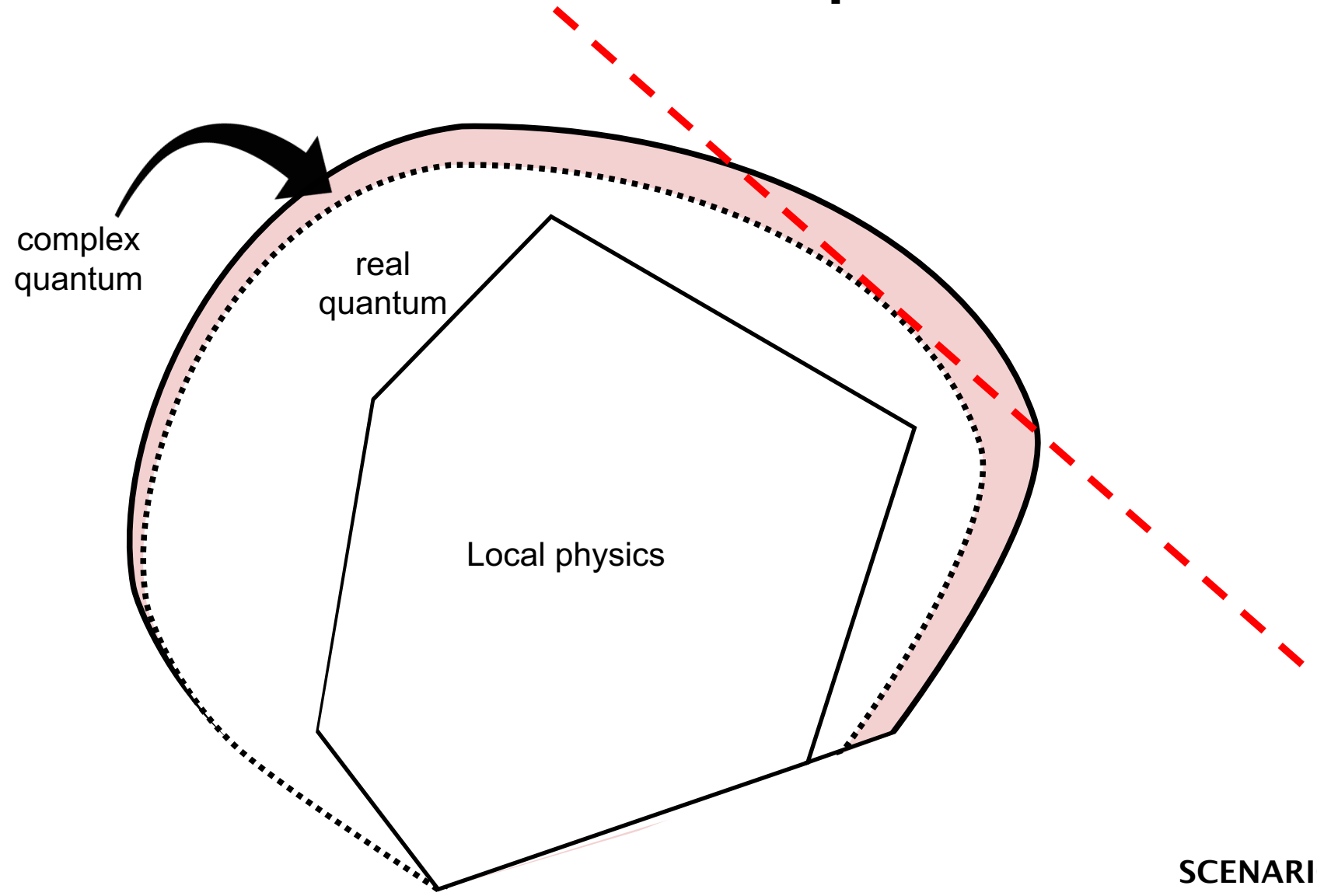
Zheng-Da Li, Ya-Li Mao, Mirjam Weilenmann, Armin Tavakoli, Hu Chen, Lixin Feng, Sheng-Jun Yang, Marc-Olivier Renou, David Trillo, Thinh P. Le, Nicolas Gisin, Antonio Acín, Miguel Navascués, Zizhu Wang (王子竹), and Jingyun Fan

Phys. Rev. Lett. **128**, 040402 – Published 24 January 2022

Physics See Viewpoint: Quantum Mechanics Must Be Complex

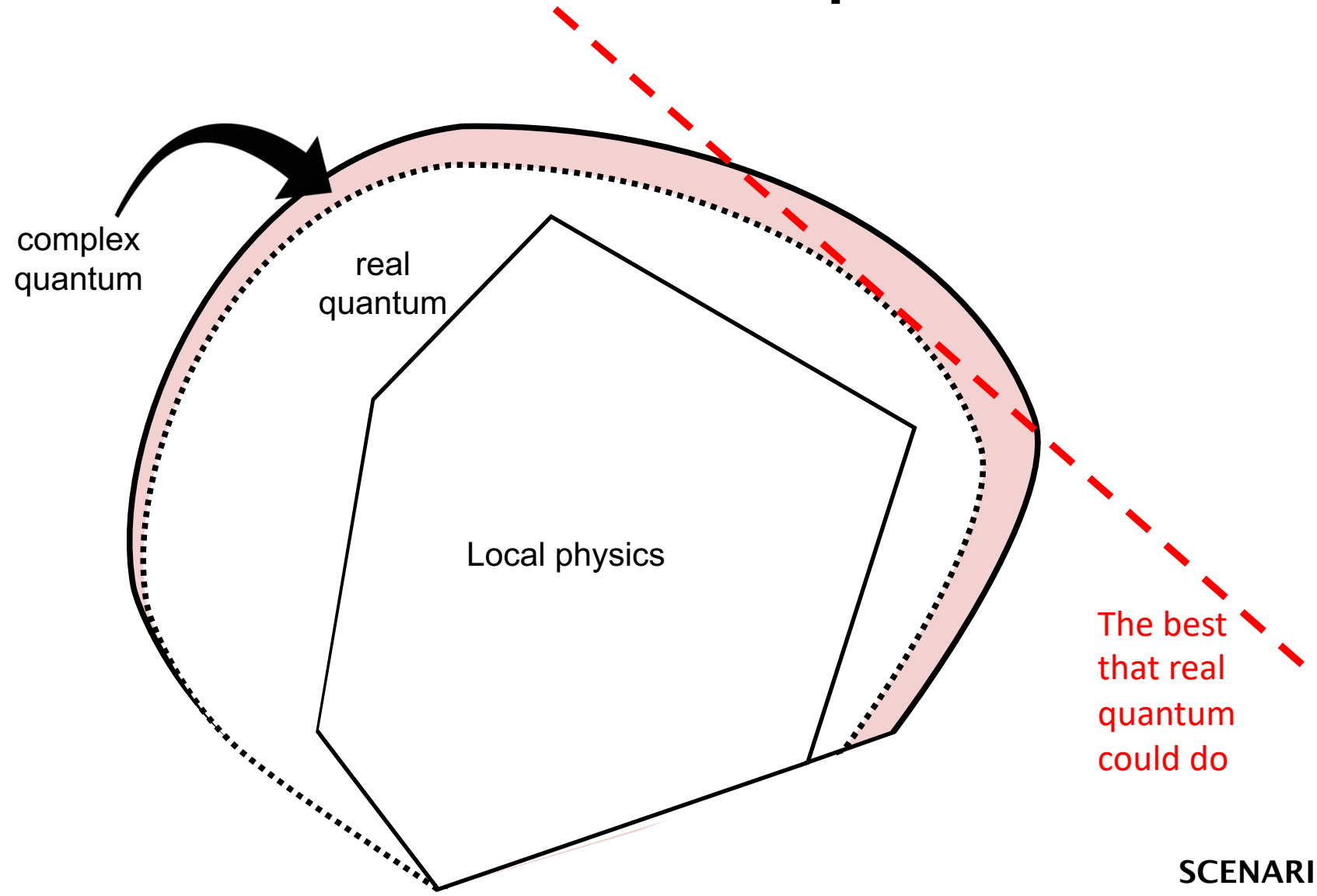
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Is QT special because it admits complex numbers?



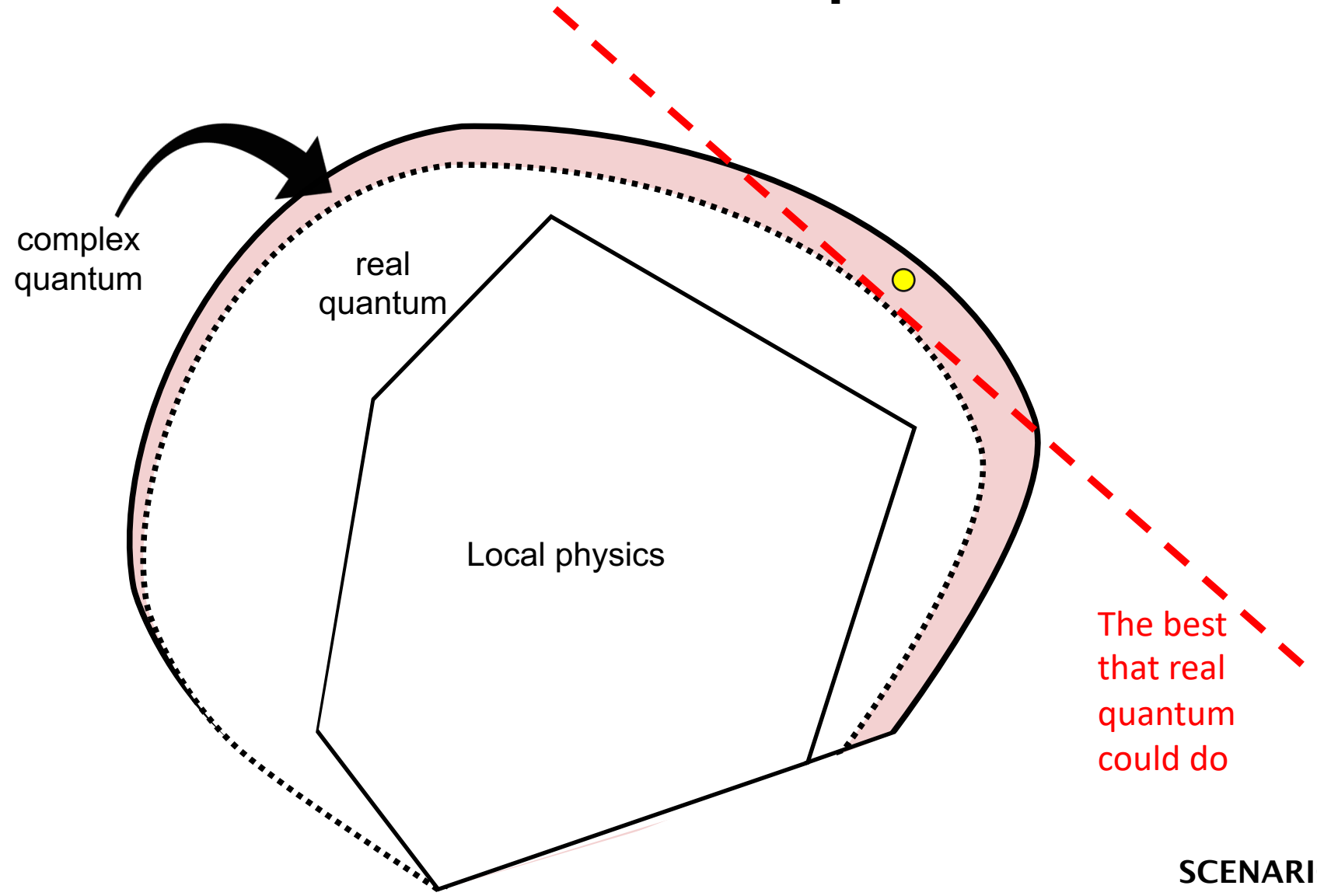
SCENARIO (3, 2, 2)
(parties, inputs, outputs)

Is QT special because it admits complex numbers?



SCENARIO (3, 2, 2)
(parties, inputs, outputs)

Is QT special because it admits complex numbers?



SCENARIO (3, 2, 2)
(parties, inputs, outputs)

More questions than answers

- Is the quantum problem decidable? Does one expect correlations in Nature to be undecidable?
- Is quantum theory special because of the norm?

Is Quantum Mechanics An Island In Theoryspace?, S Aaronson, arXiv quant-ph 0401062

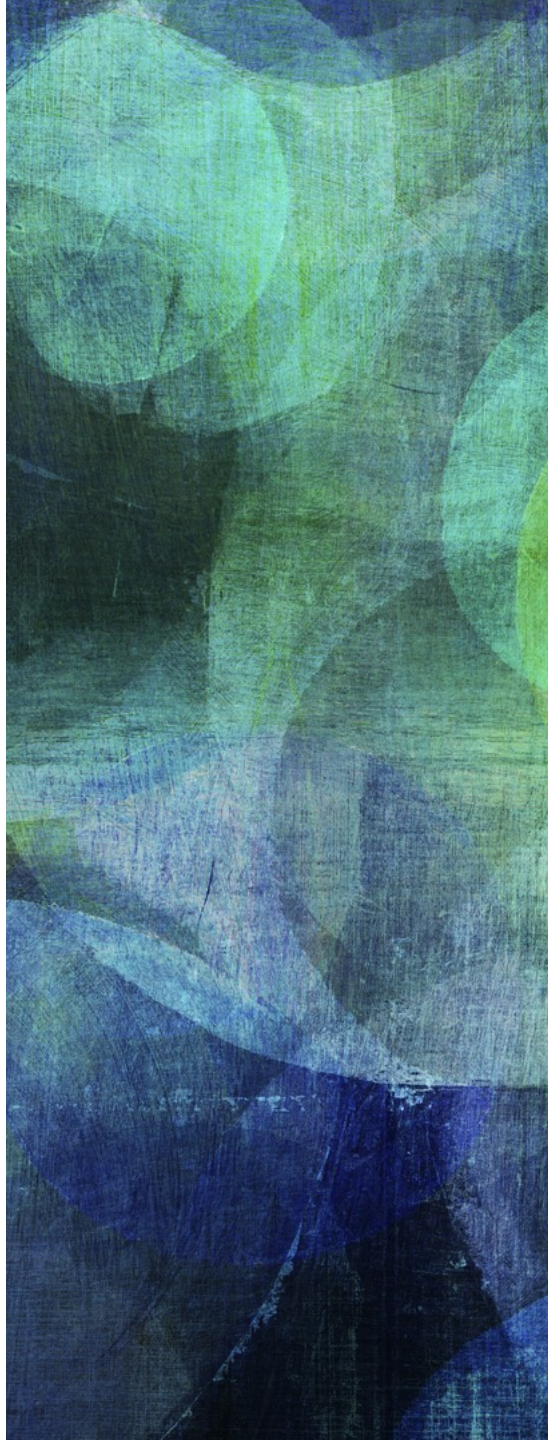
- Linearity of the Schrödinger equation?

Gisin, Phys. Lett. A 143:1–2, 1990J & Polchinski. Phys. Rev. Lett. 66:397–400, 1991.

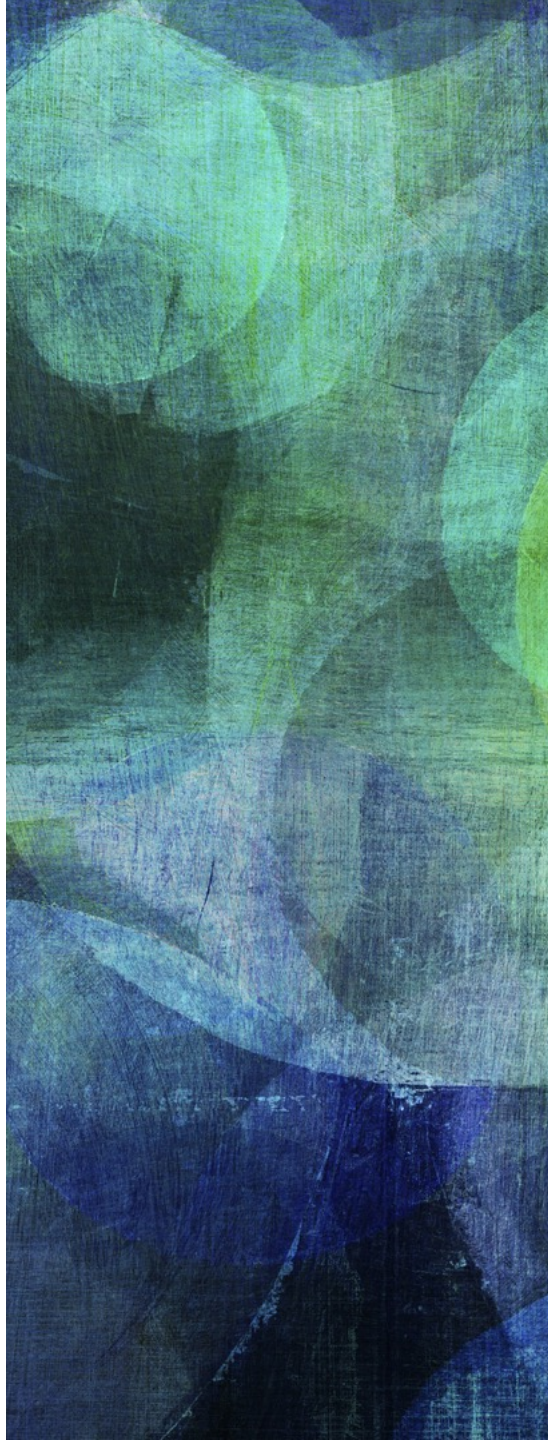
- Purification (not informational)

G. Chiribella, G. M. D'Ariano, P. Perinotti, Phys. Rev. A 81, 062348 (2010)

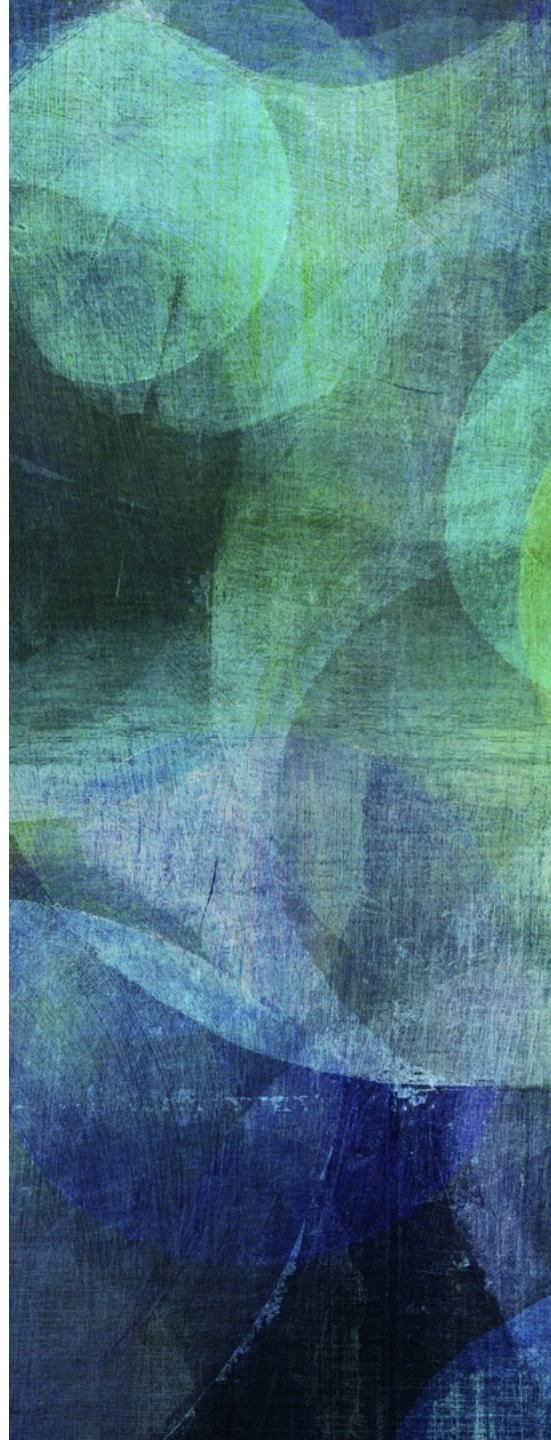
- And many many other works!



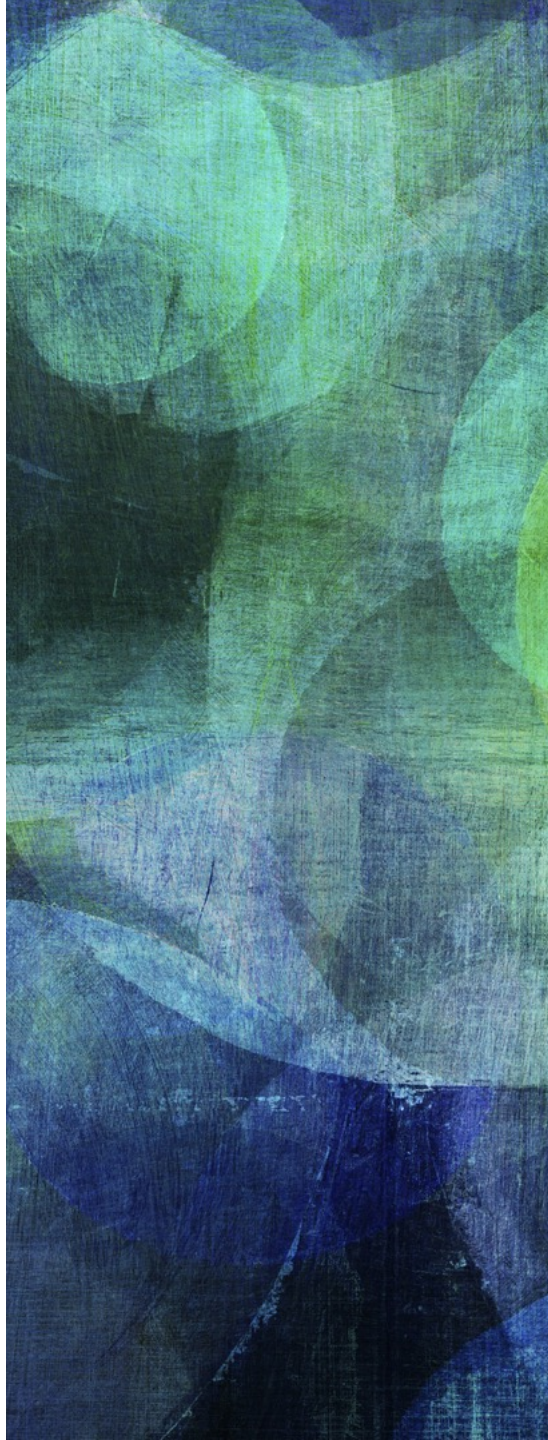
Why quantum?



Why quantum?
Why not?



Why quantum?
Why not?
Because so far nothing has been able to rule it out.



Thank you for your attention!

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