Bell's theorem, computability of quantum theory, and relativity of the 'local realism'

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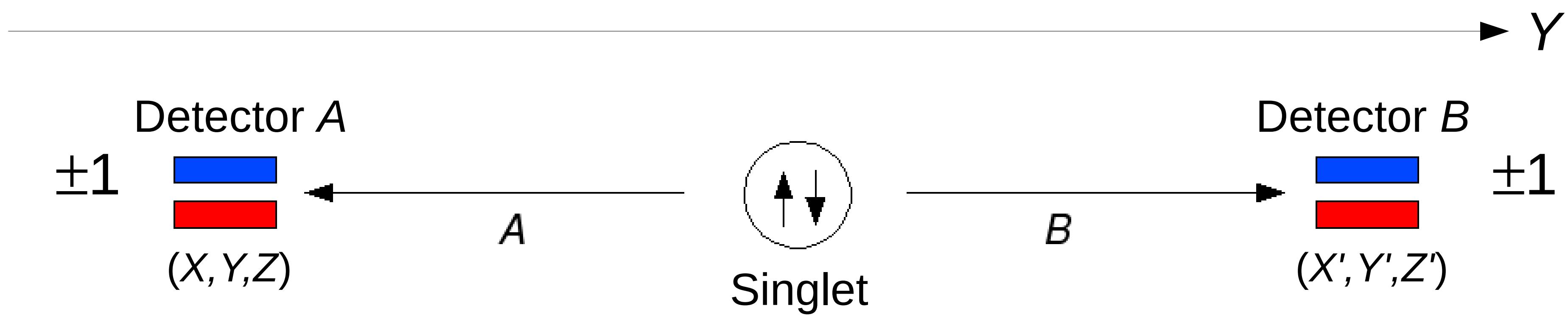
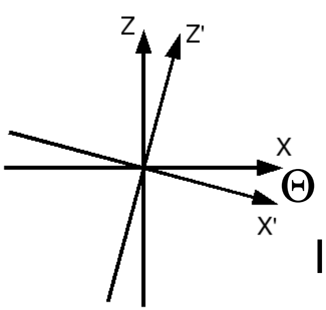
Bell's inequalities and local realism



Bell's theorem

If spins descibed by local classical variables -(**local realism**)- then:

$$|C| = |\langle S_Z^A S_{Z'}^B \rangle + \langle S_X^A S_{X'}^B \rangle + \langle S_X^A S_{Z'}^B \rangle - \langle S_Z^A S_{X'}^B \rangle| \leq 2$$



In fact, Bell's inequalities are violated

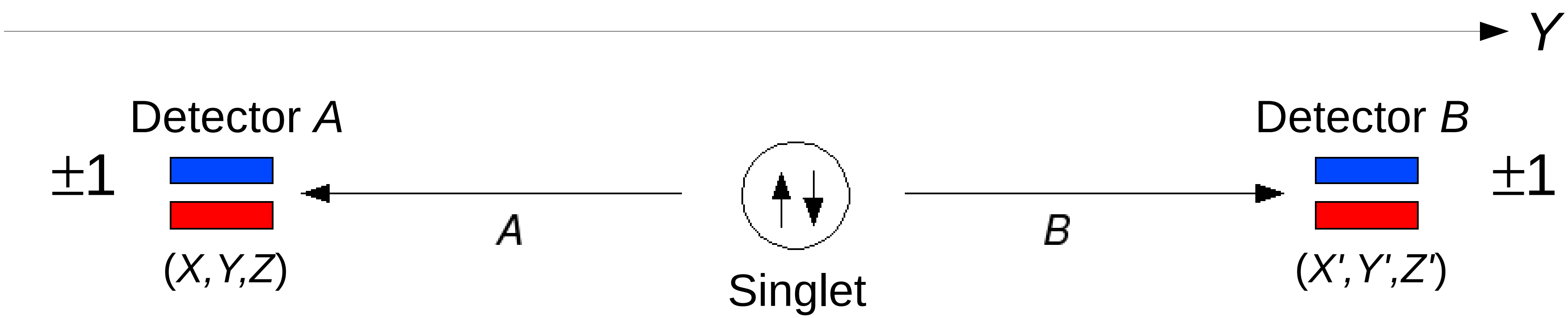
$$C(\Theta) = -2\cos\Theta + 2\sin\Theta = 2\sqrt{2}\sin(\Theta - \pi/4)$$

Conclusion: Local hidden variables as the basis of the ontology of the quantum theory excluded by observations.

Local realism is excluded by observations.

Counterexample to Bell's theorem

Local realism - local (hidden) variables



measurement parameters of A: a

measurement parameters of B: b

common causal past of measurements: λ

$A(a,\lambda)$

space-like interval
between measurements

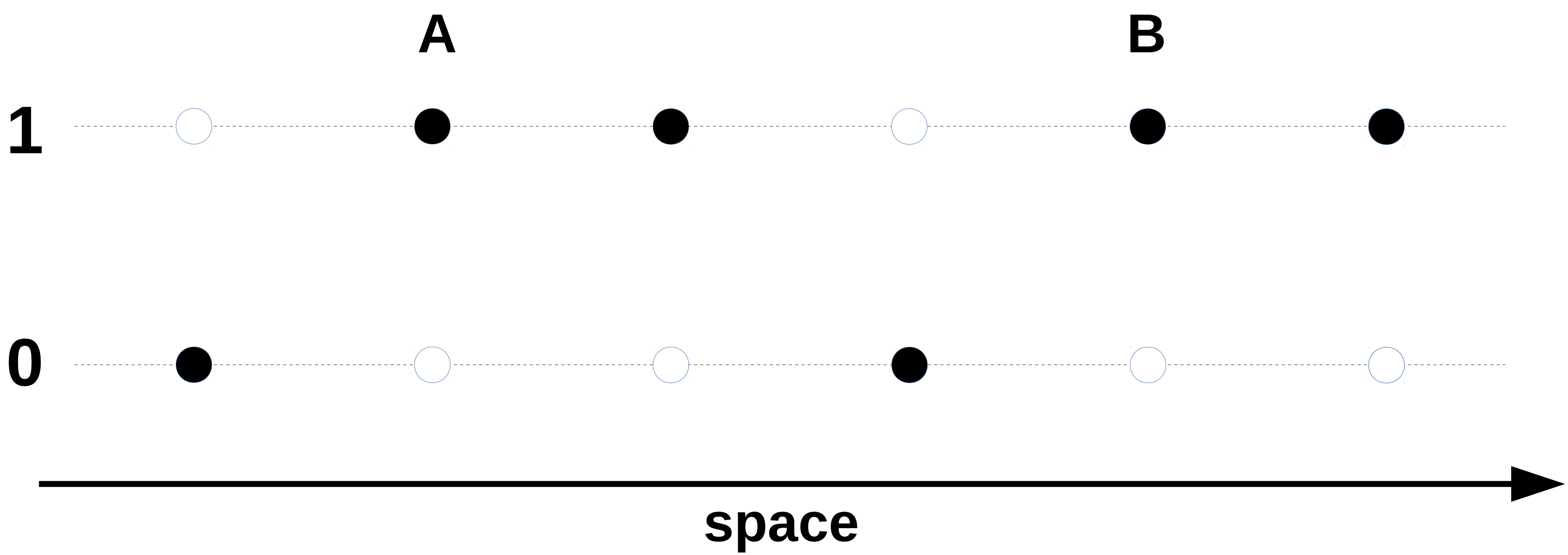
$B(b,\lambda)$

$\cancel{A(a,b,\lambda)}$

$\cancel{B(b,a,\lambda)}$

Measurements of local variables
can not infuence each other

Classical computer => local realism



$$a = 0/1$$
$$A = A(a)$$

$$b = 0/1$$
$$B = B(b)$$

State of a computer memory
is decribed by local classical variables

Computability of quantum physics

Solution of general Diophantine equation - unresolvable problem

Algorithmic resolvability (computability) of quantum theory:

1. System states – Hilbert space vectors (column of numbers)
2. Evolution – unitary transforations of vectors or solution of systems of linear differential equations
3. Measurements – inner products of vectors

Formally speaking:
Fragments of quantum reality permit exhaustive modeling in classical computer (with arbitrarily high precision)
Particularly: quantum computers may be simulated by classical computers (and such simulators actually exist)

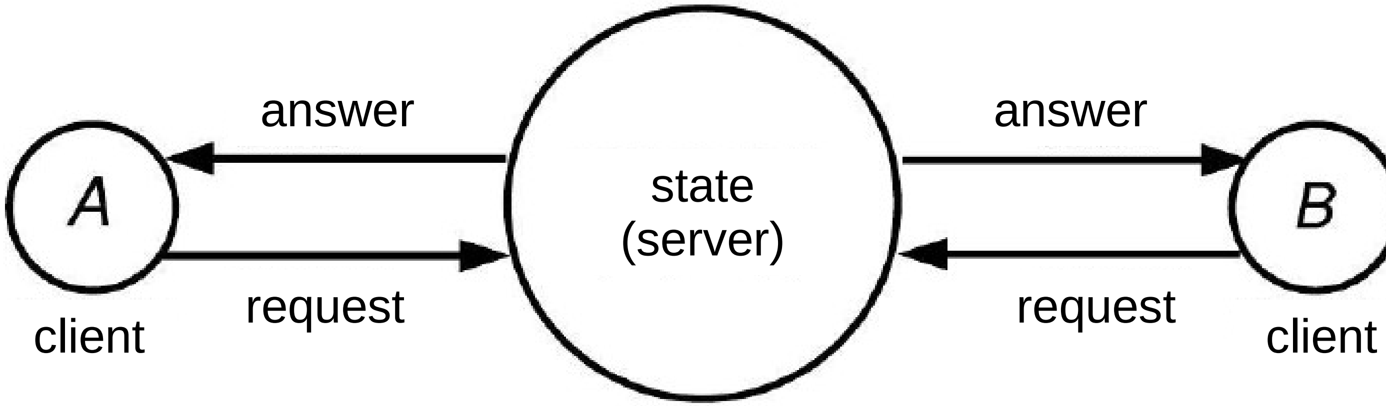
B. Julia-Dıaz, J.M. Burdis, and F. Tabakin.
Qdensity – a Mathematica quantum computer simulation.
arXiv:quant-ph/0508101.

1. Quantum dynamics are computable with classical computers.

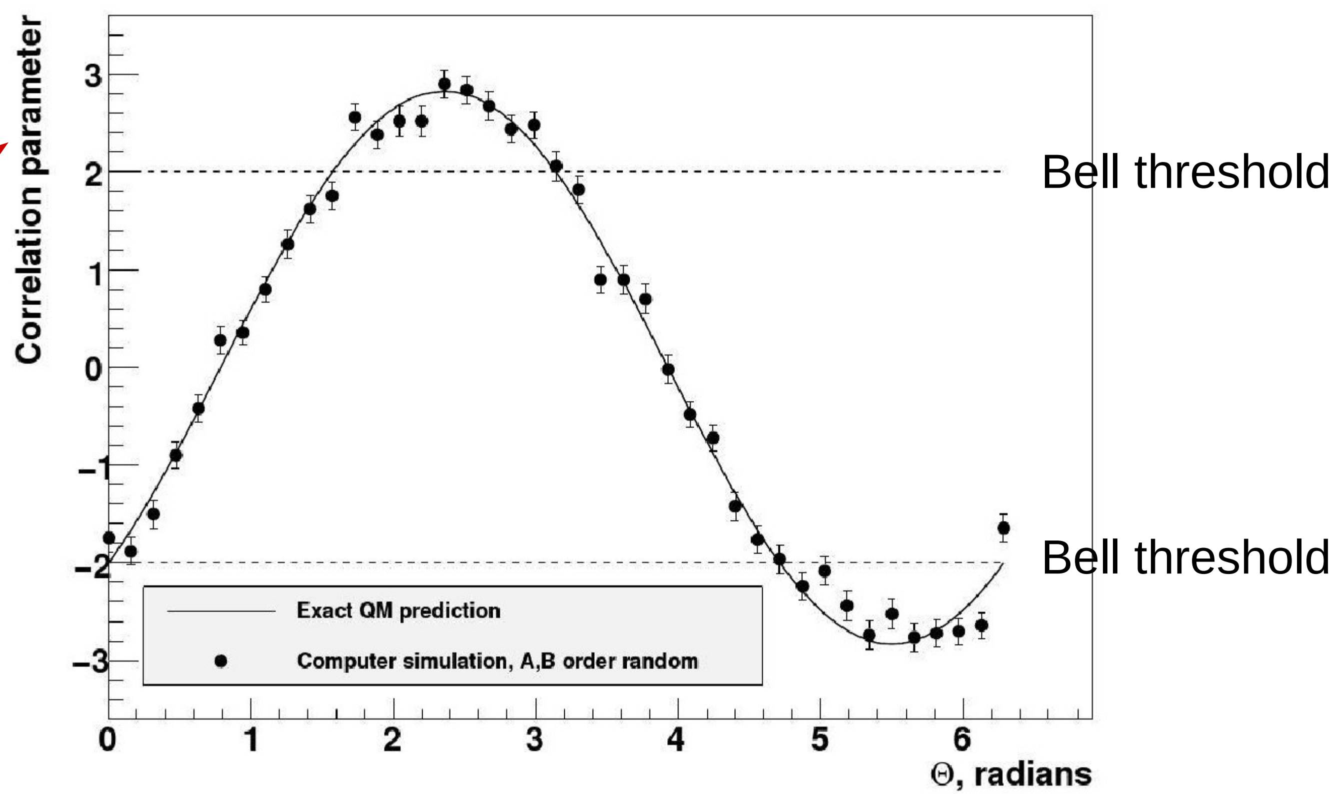
2. Classical computers are systems with local realism

An emergent quantum behavior of a classical computer

Program - simulator of correlated spins in EPR-pair



Bell's inequality is violated!



An emergent quantum behavior of classical computer - quantum simulator

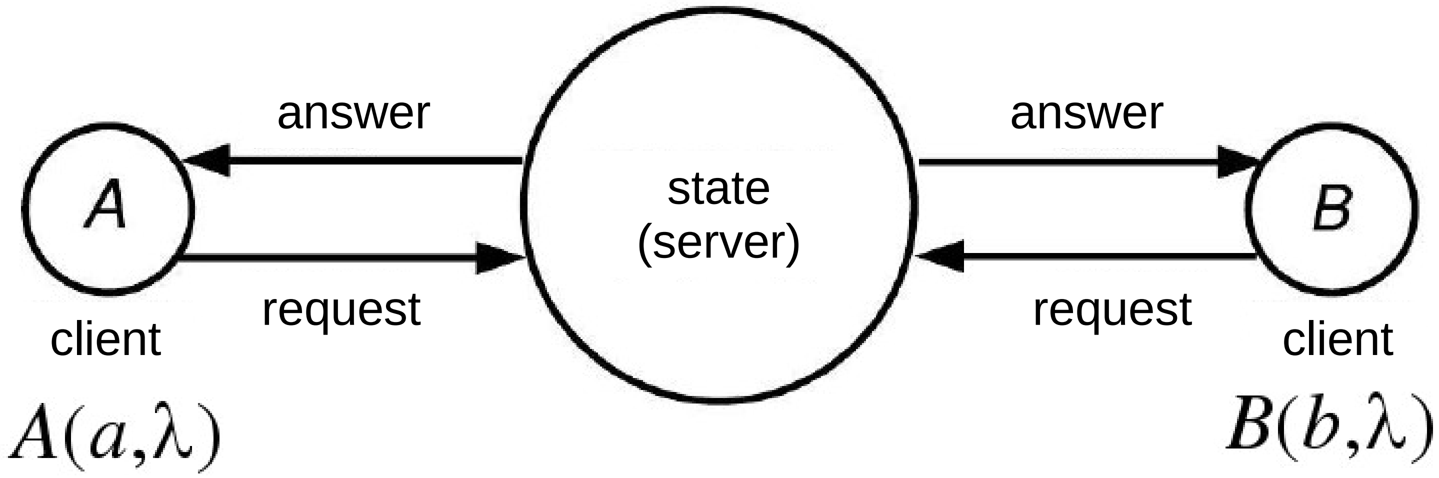
Simulation of devices and simple quantum systems:
The simulated device detects quantum behavior
without any flaws - it detects real quantum behavior

Simulation of observers together with quantum system:
- The observer can not guess that it is in a virtual reality, and he has the right to apply Bell's theorem to his reality.

The ontological base of quantum behavior of a quantum simulator
is classical local structure of the computer,
therefore classical local realism
<u>may lay</u> in the base of quantum behavior.

- Contradiction with conculusion of Bell's theorem and observations

The origin of contradiction with Bell's theorem



In the reality of the program: a – the direction of measurement axis A
b – the direction of measurement axis B
λ – ramdom generator state

Functions take the form: A(a,b,λ) и B(b,a,λ) -

a, b, λ do not satisfy the condition of local realism

In the computer hardware: a, b, λ are local register states -

a, b, λ do satisfy the condition of local realism

a, b, λ are no local and local at the same time!!!

Local realism is relative to …? -
to layear of realyty (and reality may be multiple layer)

The contradiction of the counter-example with Bell's theorem is resolved:

Building of a counter-example to the Bell's theorem has become possible due to the fact that the usual proof of the Bell's theorem does not take into account the possibility of different layers of reality and ignored the possibility for local realism **to be relative** to layers of reality.

What are layers of reality generally?

In the considered example one layer of reality (simulated reality) is an **image** in the **substrate** of other, more deep reality (computer hardware and all our physical world)

<u>**The relation substrate-image may be used as general definition to separate different layers of reality.**</u>

The logical possibility of existence of different layers of reality
is not a hypothesis:

- it was explicitly proven by model with computer simulated reality

Generalization

Quantum dynamics of our 'real world' may be an image in some clasical and local substrate which plays a role of hidden local classical parameters of quantum physics.

There is no contradiction with Bell's theorem. The proposition of the Bell's theorem is that there are no hidden classical local parameters of quantum dynamics in the same layer of reality in which the quantum danamics is considered.

Question: If our quantum dynamics actually is an image in some substrate, what can we say about the nature of this substrate?

1. The most strightforward possibility: all our quantum world is a simulation in a giant classical 'computer' - the substrate (deep reality) is this 'computer'

To simulate the electronic shell of the only one uranium atom (Z=92) one needs $10^{4\times92\times3\times2}=10^{2208}$ numbers but there are only 10^{153} Planckian cells in all Universe event horizon

One needs extremely large reservoir to store such a 'computer' - It is unlikely that for such a computer locality can be understood by primitive spatial way.

2. All our quantum world is an image in classical, but not local substrate

A spatial resevoir is not needed for such a substrate because the mode of existence of this substrate is completely spaceless

How can such classical but not local substrate look like?

How can classical but not local substrate of quantum world looks like?

Analogy

Trillionth decimal digit of √2:
- Nobody knows what is it, there is no information carrier where this digit is written.
- This object does not exist in physical world.
- But anybody who calulate it obtain the same result because
  trillionth decimal digit of √2 objectively existed before any calculations of it.

This is an example of completely space-less objective existence.

Our mathematics is a classical structure

Calculations is a process similar to measurement.
Calculations do not influence the object under interest like
measurements do not influence the value of **classical** physical quantities

Classical but not local substrate of quantum world may be similar in some features to abstract mathematical structure

BUT it is not a purely mathematical structure.
All known mathematical structures are models, but the substrate is not a model,
it is a 'genuine final reality'

There is no reason to insist on 'pure abstract' nature of classical no-local substrate.

The connection between quantum physics and substrate may be more 'material' - (like in case of connection computer - virtual reality)

It may be also something intermediate between an abstract essence and something material

We have some hints that wanted 'Final physical theory' maybe too naive notion, since the 'Final theory' can appear not a physical theory in the proper sense of the word. And not mathematical one.

It is possible that at very deep onthological level the connection between physics and mathematics is much more close than it looks from higher ontological levels

Physics and mathematics may originate from one root and be different sides or different limited cases of the same deep entity. Isn't this an origin of «The Unreasonable Effectiveness of Mathematics in the Natural Sciences» (E. Wigner)?

Summary

Starting from simple example with simulation of quantum systems by usual computers we came to the notion of different (maybe many) layers of reality and to conclusion that the world may be more complicated than it looks from pure physics or from pure mathematics.

It would be very difficult to penetrate to the nature of a substrate if our reality actually is something like image in this substrate.

This can put an absolute limit to our knowledge of nature.