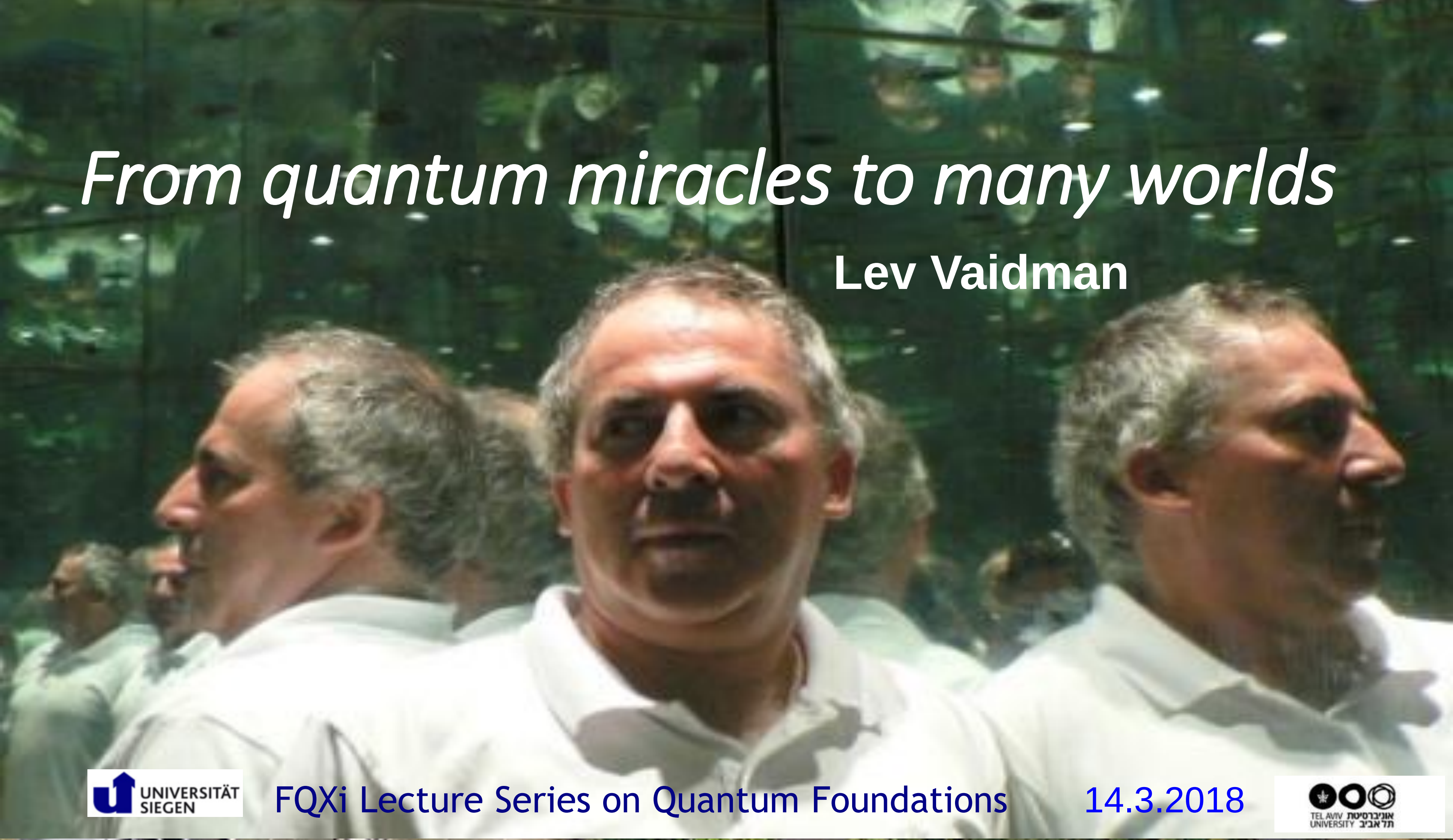
From quantum miracles to many worlds

Lev Vaidman



UNIVERSITÄT SIEGEN

FQXi Lecture Series on Quantum Foundations

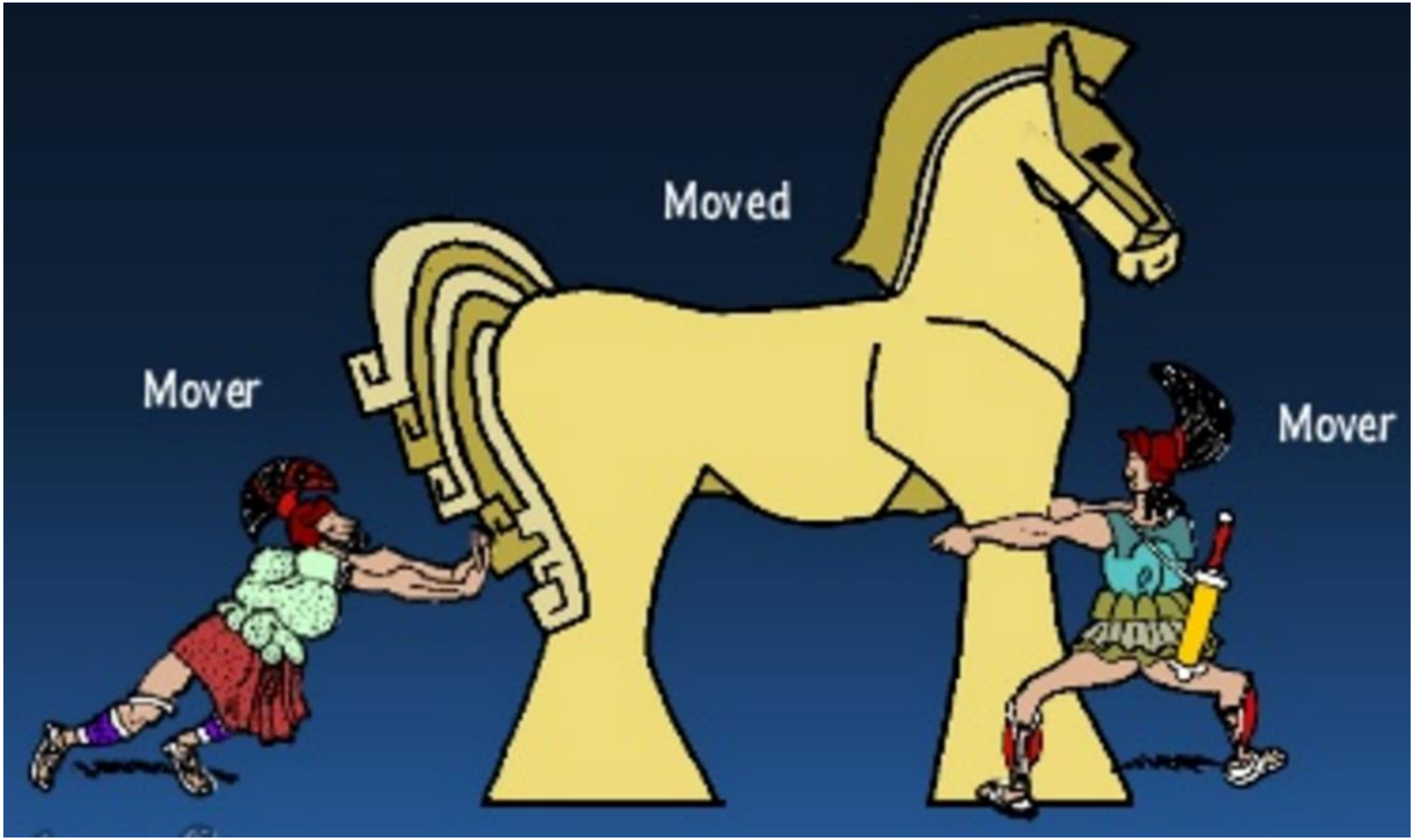
14.3.2018

TEL AVIV UNIVERSITY אוניברסיטת תל־אביב

GIF

TAU Q

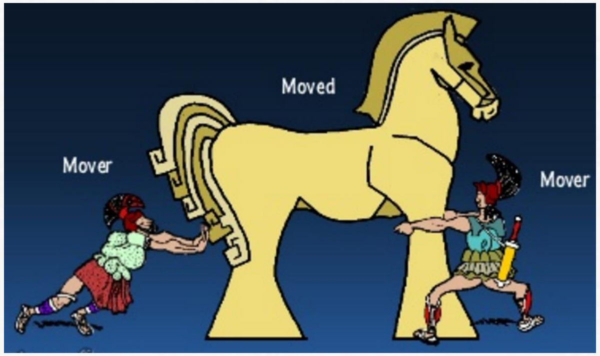
Good explanation



Local action

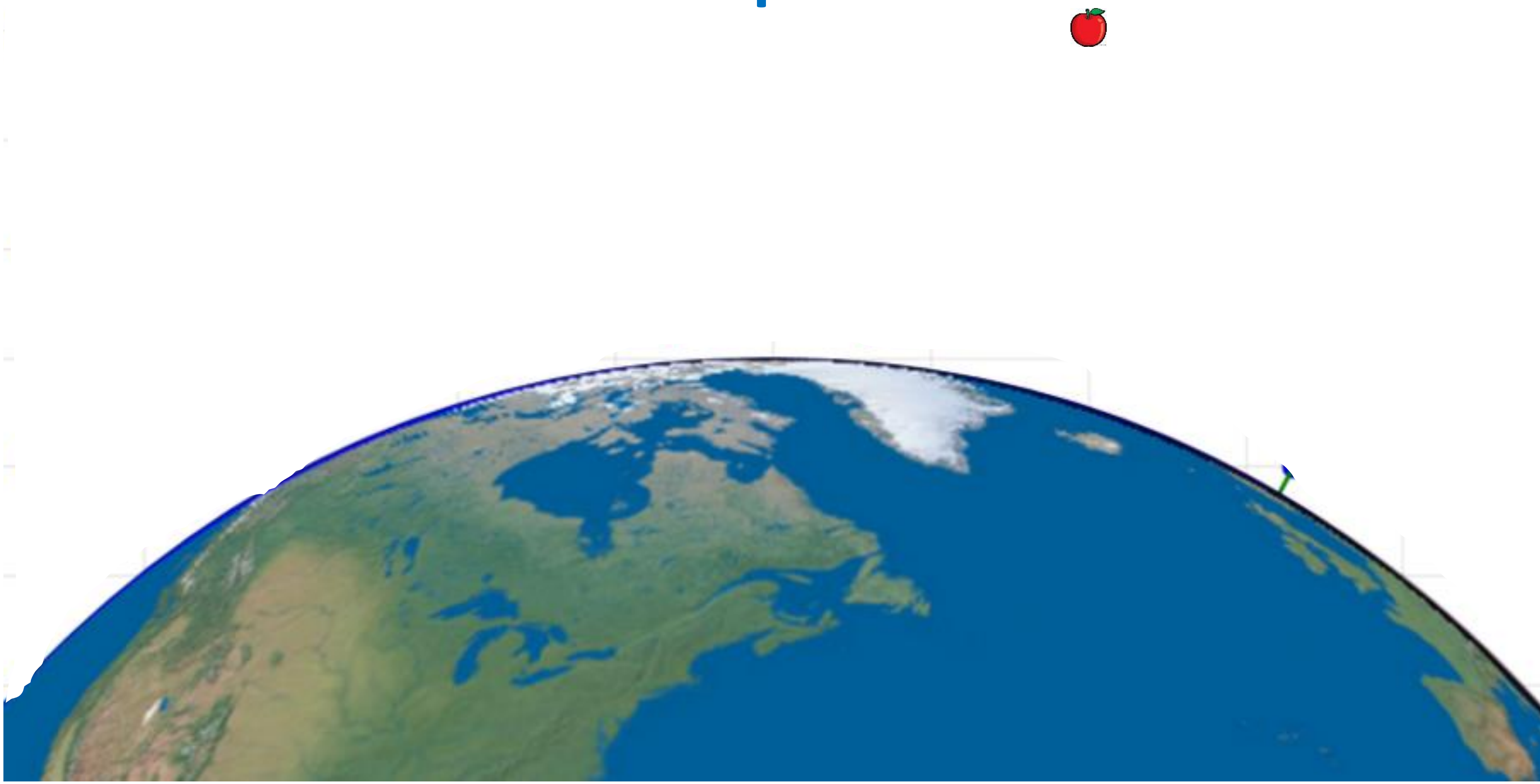
Good explanation

Local action



Tis inconceivable, that inanimate brute Matter, should (without ye mediation of something else wch is not material), operate upon & affect other matter wthout mutual contact; as it must if gravitation in the sense of Epicurus, be essential & inherent in it. And this is one reason why I desired you not to ascribe innate gravity to me. That gravity should be innate inherent & essential to matter so yt one body may act upon another at a distance through a vacuum wthout the mediation of any thing else & by & through wch their action and force may be conveyed from one to another is to me such an absurdity that I beleive no man who has in philosophical matters any competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws, but whether this agent be material of immaterial is a question I left to ye consideration of my readers. (Newton, 1959-1977, III, pp. 253-245)

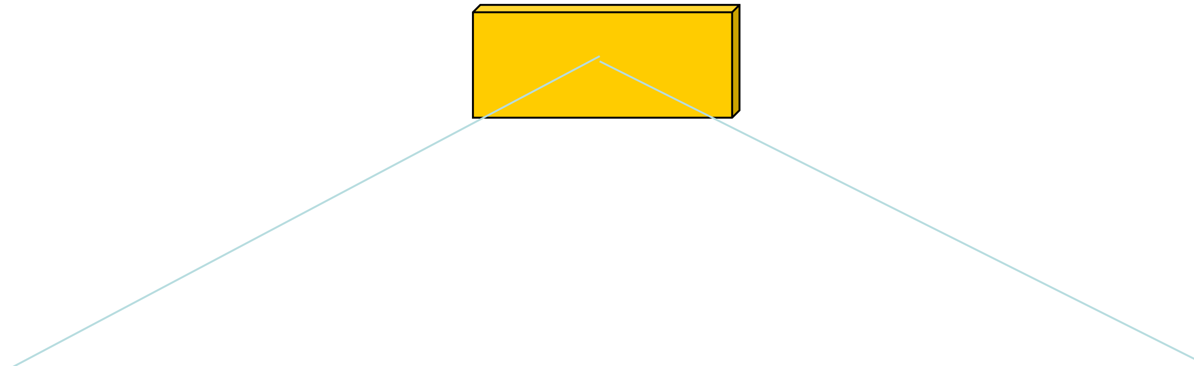
Good explanation



Objects create fields

Fields affect other objects locally

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



$\vec{F} = m\vec{a}$ local action Good explanation

$\Uparrow$

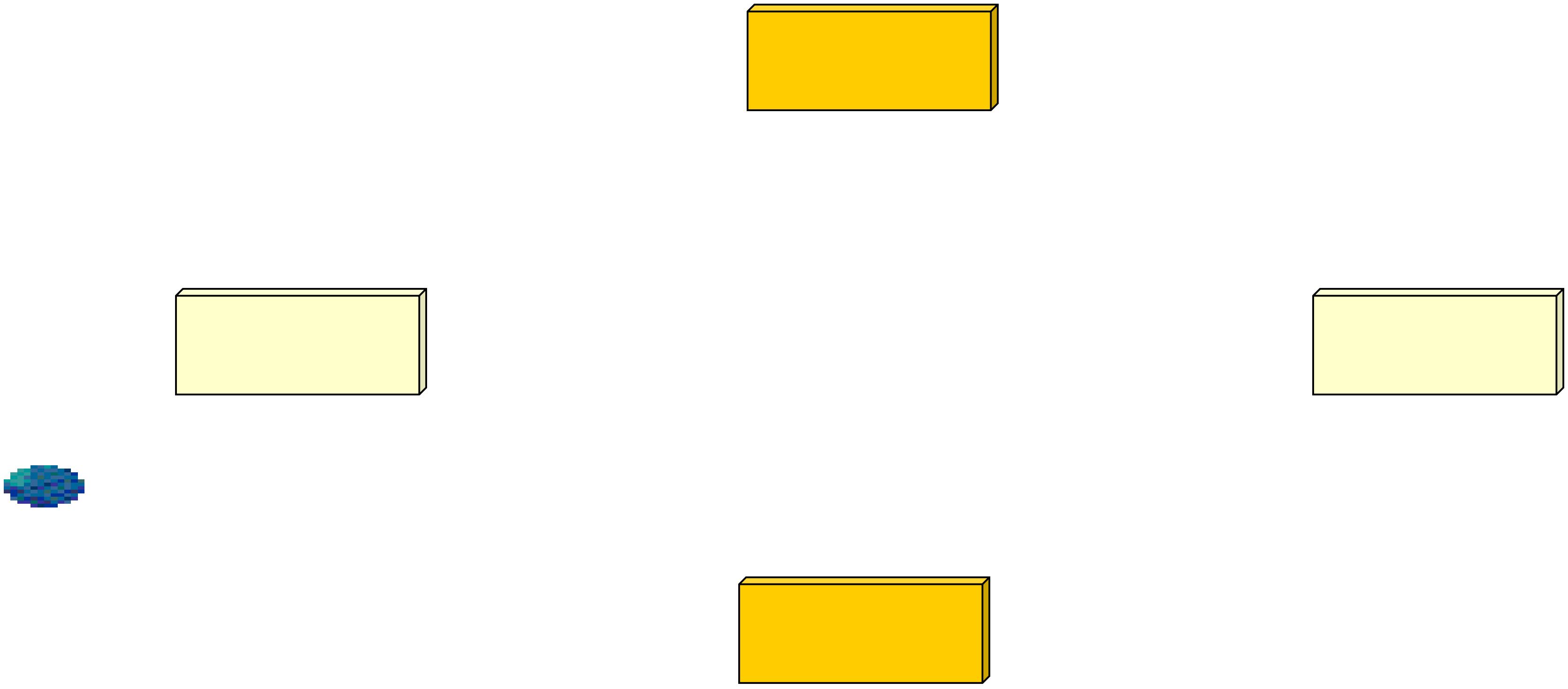
Is it an explanation?

$$\delta S = \delta \int_{t_1}^{t_2} \left(\frac{p^2}{2m} - U(\vec{r}, t) \right) dt = 0$$

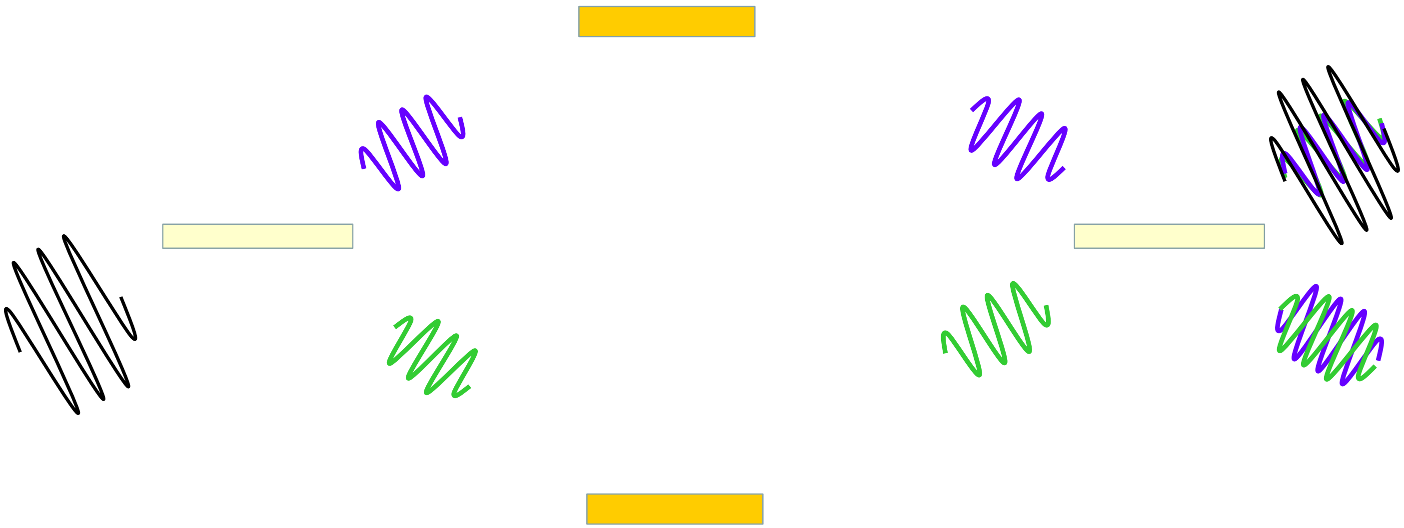
global picture

Classical physics failed to provide an explanation for

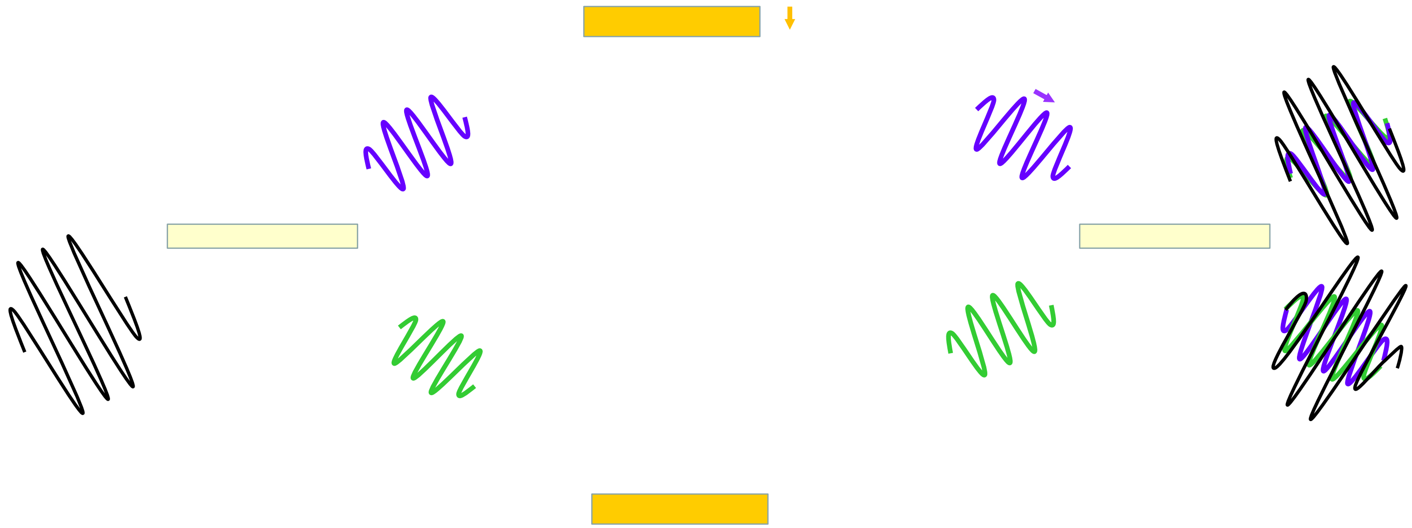
Mach Zehnder Interferometer with particles



Quantum mechanics: particles are waves



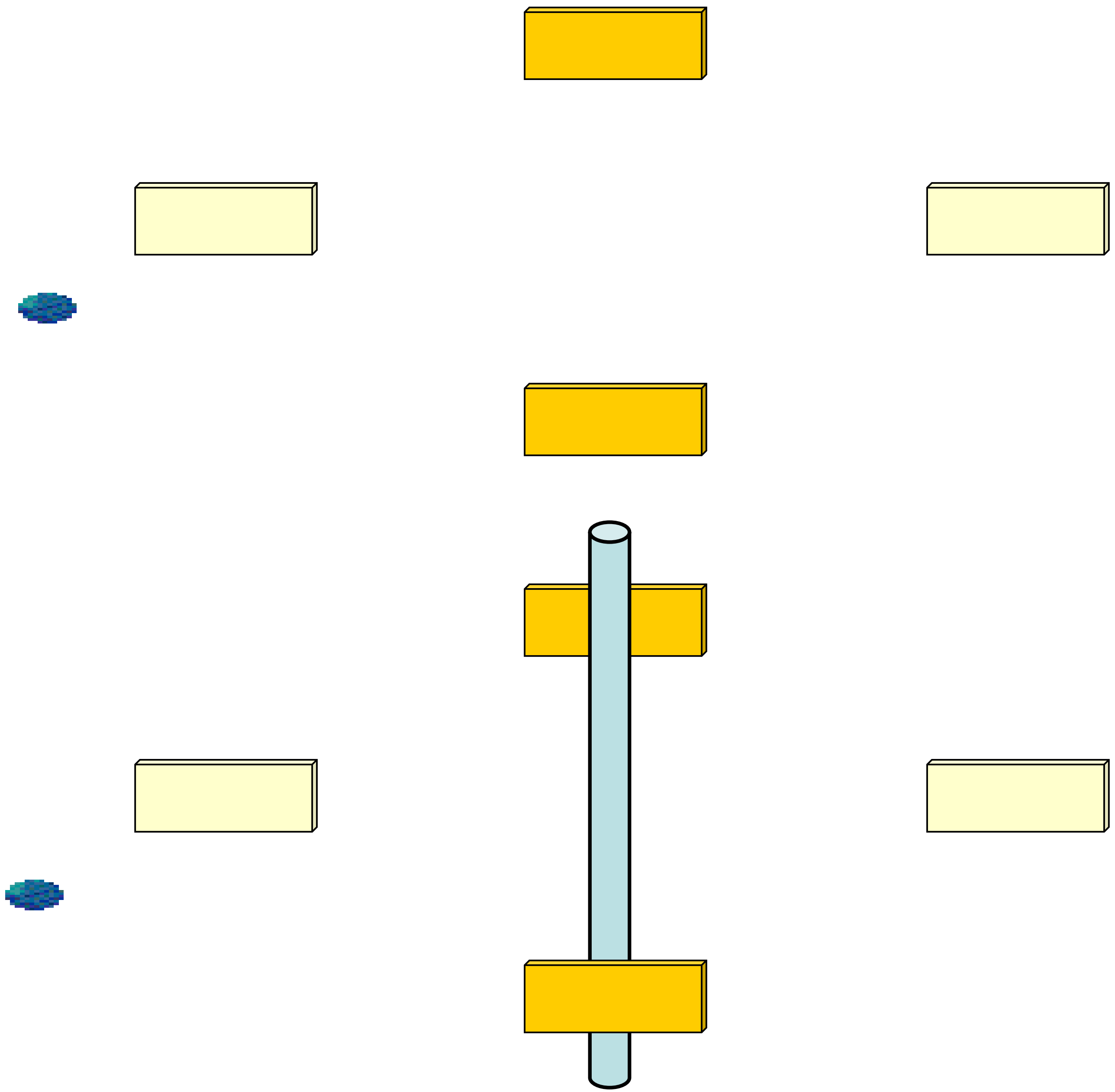
Quantum mechanics: particles are waves



Quantum physics provides a good explanation:

Local interactions and interference

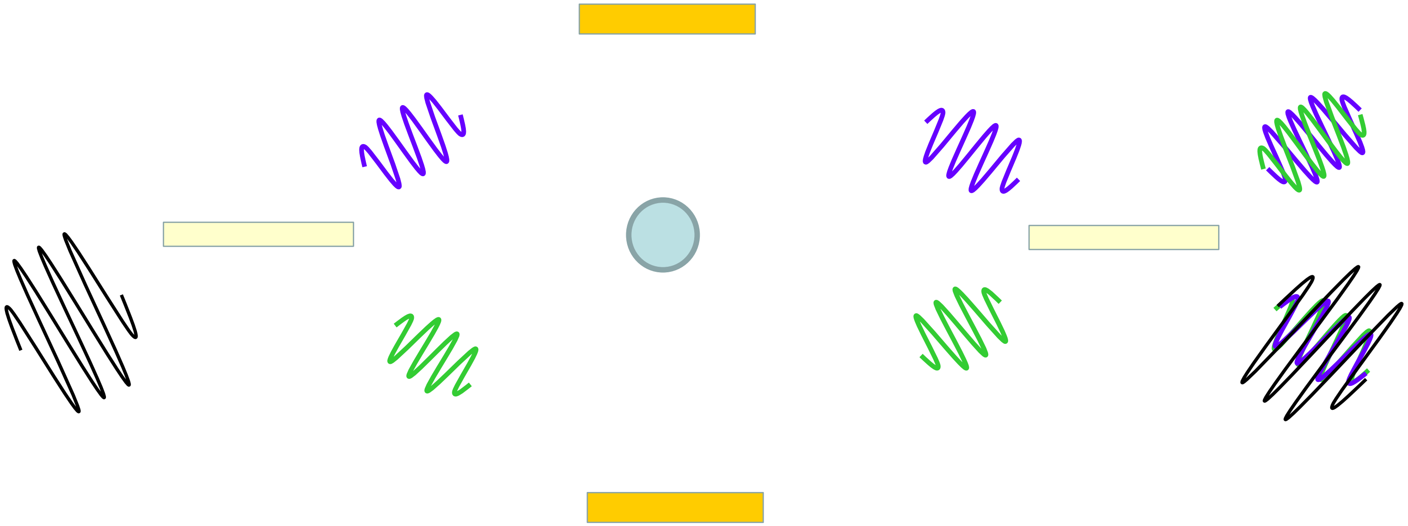
Aharonov-Bohm Effect: a counter example?!



Aharonov-Bohm Effect: a counter example?!

The solenoid causes a relative phase without classical lag?!

Nonlocality: Electromagnetic potential acts in a global topological way?!



Do we have only global explanation $\delta S = 0$ **?**

Aharonov-Bohm Effect: a counter example?!

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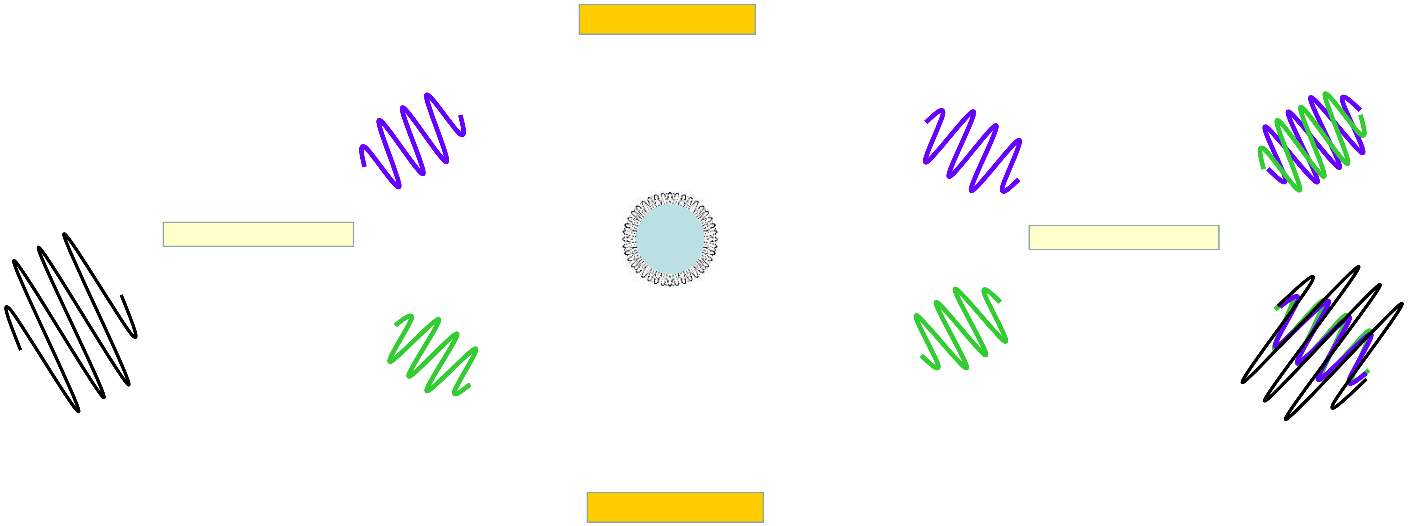


Do we have only global explanation $\delta S = 0$ **? No!** Role of Potentials in the Aharonov-Bohm Effect
L. Vaidman, *Phys. Rev.* A R86, 040101 (2012)

AB effect *does* have local explanation if everything, including the source of the magnetic flux is treated quantum mechanically

The AB phase is acquired by the solenoid, entangled with the electron, due to local action of electromagnetic field of the electron

Quantum physics provides a good explanation:

Local interactions, interference and entanglement

The EPR argument

Albert Einstein

Boris Podolsky

Nathan Rosen

MAY 15, 1935 PHYSICAL REVIEW VOLUME 47

Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

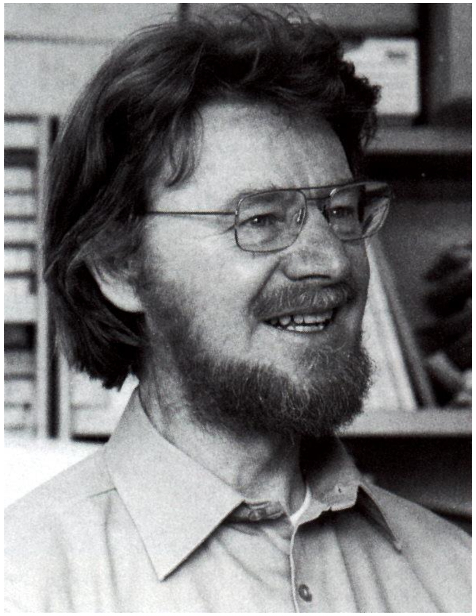
A. EINSTEIN, B. PODOLSKY AND N. ROSEN, *Institute for Advanced Study, Princeton, New Jersey*

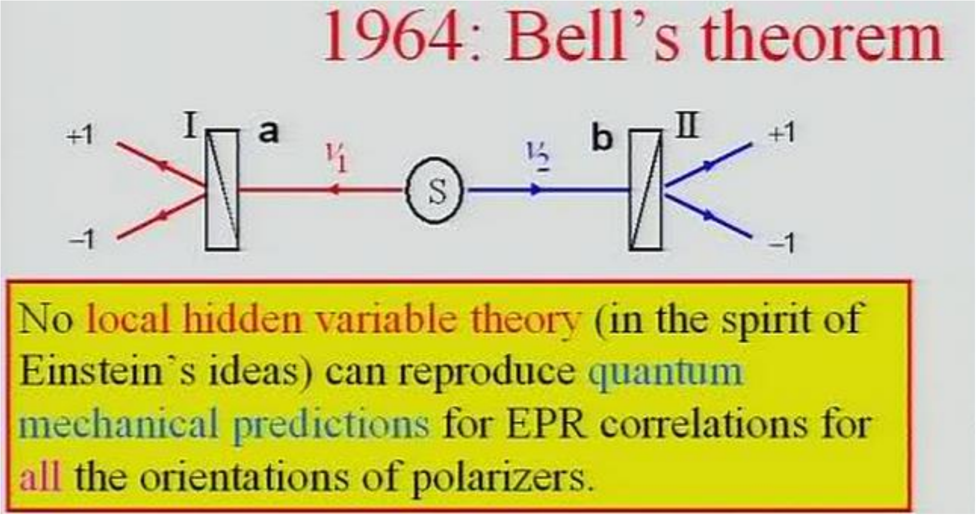
(Received March 25, 1935)

In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system. In quantum mechanics in the case of two physical quantities described by non-commuting operators, the knowledge of one precludes the knowledge of the other. Then either (1) the description of reality given by the wave function in quantum mechanics is not complete or (2) these two quantities cannot have simultaneous reality. Consideration of the problem of making predictions concerning a system on the basis of measurements made on another system that had previously interacted with it leads to the result that if (1) is false then (2) is also false. One is thus led to conclude that the description of reality as given by a wave function is not complete.

While we have thus shown that the wave function does not provide a complete description of the physical reality, we left open the question of whether or not such a description exists. We believe, however, that such a theory is possible.

Bell: Quantum theory cannot be completed





Quantum theory has miracle: action at a distance

Bell's Theorem, Quantum Theory and Conceptions of the Universe
Fundamental Theories of Physics Volume 37, 1989, pp 69-72

Going Beyond Bell's Theorem

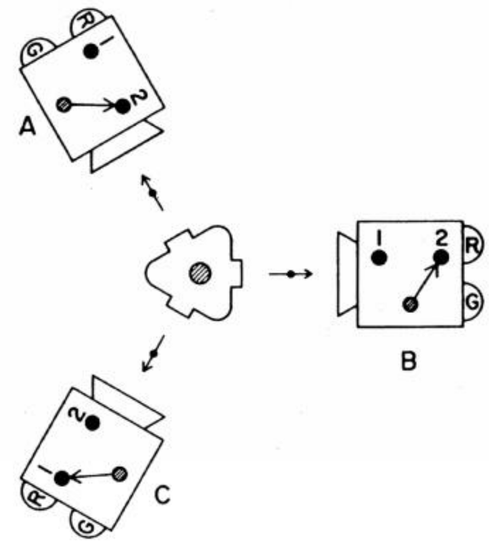
Daniel M. Greenberger, Michael A. Horne, Anton Zeilinger

Quantum mysteries revisited

N. David Mermin
Laboratory of Atomic and Solid State Physics, Cornell University, Ithaca, New York 14853-2501

(Received 30 March 1990; accepted for publication 28 April 1990)

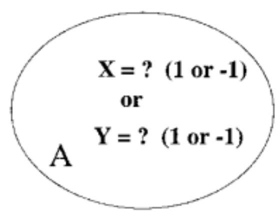
A gedanken gadget is described, based on an idea of Greenberger, Horne, and Zeilinger, that provides a more powerful demonstration of quantum nonlocality than Bell's analysis of the Einstein–Podolsky–Rosen experiment.

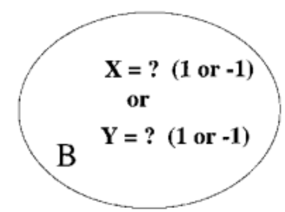


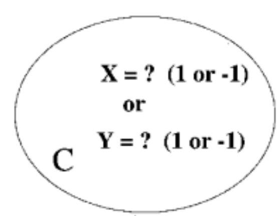
Variations on the Theme of the Greenberger–Horne–Zeilinger Proof

Foundations of Physics, Vol. 29, No. 4, 1999

Lev Vaidman[1]







The GHZ game

X=? or Y=?

B

1 or -1

Winning conditions

$$\begin{cases} \overset{+}{X_A}\,\overset{+}{X_B}\,\overset{-}{X_C} = -1 \\ \overset{+}{X_A}\,\overset{+}{Y_B}\,\overset{+}{Y_C} = 1 \\ \overset{+}{Y_A}\,\overset{+}{X_B}\,\overset{+}{Y_C} = 1 \\ \overset{+}{Y_A}\,\overset{+}{Y_B}\,\overset{-}{X_C} \neq 1 \end{cases}$$

$$P_{win}^{Classical} = 3/4$$

$$P_{win}^{Quantum} = 1$$

$$X_A{}^2 X_B{}^2 X_C{}^2 Y_A{}^2 Y_B{}^2 Y_C{}^2 = -1$$

X=? or Y=?

A

1 or -1

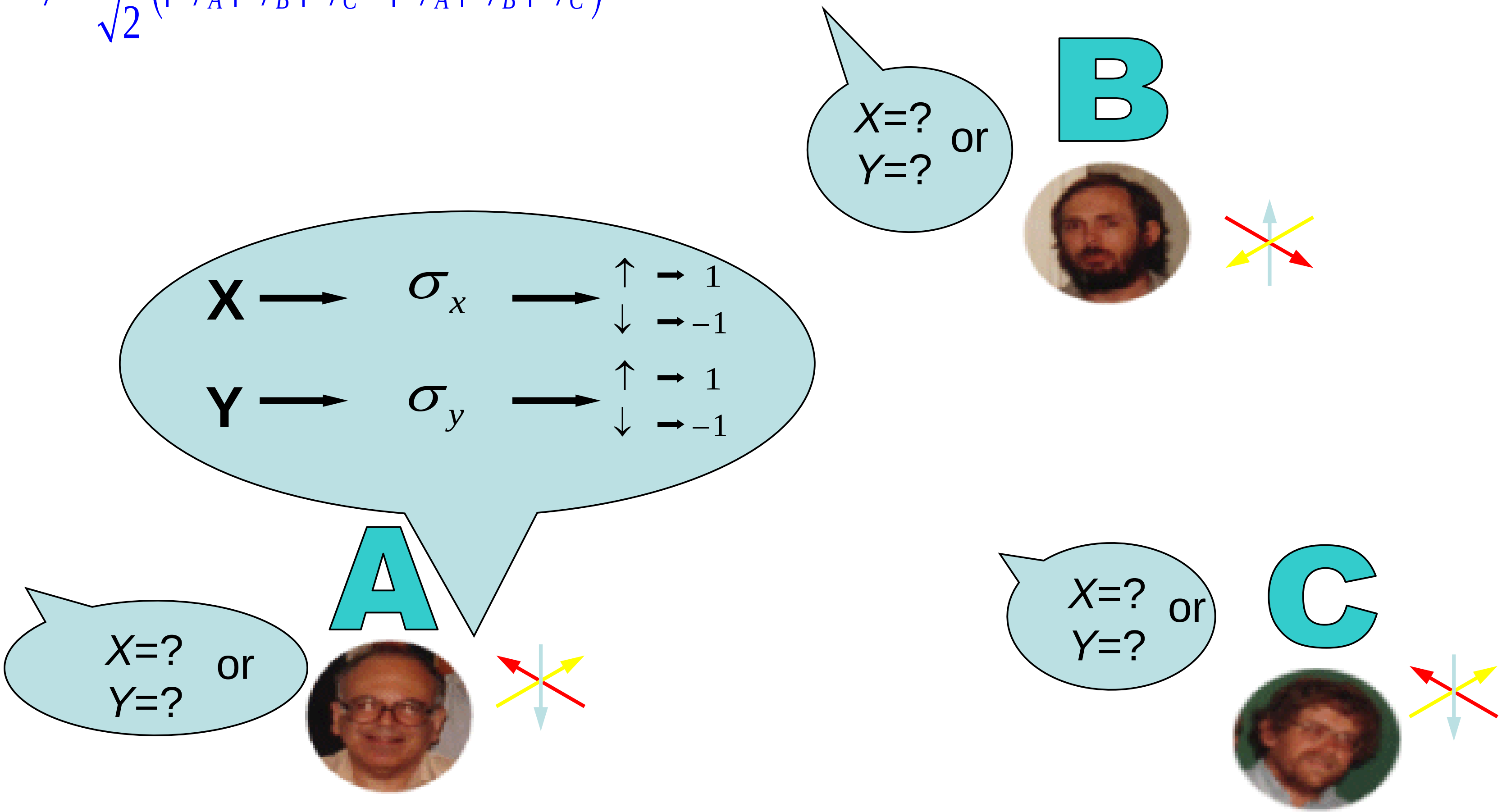
X=? or Y=?

C

1 or -1

The GHZ Game Quantum Strategy

$$|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_A|\uparrow\rangle_B|\uparrow\rangle_C - |\downarrow\rangle_A|\downarrow\rangle_B|\downarrow\rangle_C\right)$$



$$\boxed{|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_A |\uparrow\rangle_B |\uparrow\rangle_C - |\downarrow\rangle_A |\downarrow\rangle_B |\downarrow\rangle_C\right)}$$

$$\boxed{\begin{aligned} |\uparrow_z\rangle &= \frac{1}{\sqrt{2}}\left(|\uparrow_x\rangle + |\downarrow_x\rangle\right) \\ |\downarrow_z\rangle &= \frac{1}{\sqrt{2}}\left(|\uparrow_x\rangle - |\downarrow_x\rangle\right) \end{aligned}}$$

$$|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow_z\rangle_A |\uparrow_z\rangle_B |\uparrow_z\rangle_C - |\downarrow_z\rangle_A |\downarrow_z\rangle_B |\downarrow_z\rangle_C\right)$$

$$= \frac{1}{2}\left(|\uparrow_x\rangle_A |\uparrow_x\rangle_B |\downarrow_x\rangle_C + |\uparrow_x\rangle_A |\downarrow_x\rangle_B |\uparrow_x\rangle_C + |\downarrow_x\rangle_A |\uparrow_x\rangle_B |\uparrow_x\rangle_C + |\downarrow_x\rangle_A |\downarrow_x\rangle_B |\downarrow_x\rangle_C\right)$$

$$= \frac{1}{2}\left(|\uparrow_x\rangle_A |\uparrow_y\rangle_B |\uparrow_y\rangle_C + |\uparrow_x\rangle_A |\downarrow_y\rangle_B |\downarrow_y\rangle_C + |\downarrow_x\rangle_A |\downarrow_y\rangle_B |\uparrow_y\rangle_C + |\downarrow_x\rangle_A |\uparrow_y\rangle_B |\downarrow_y\rangle_C\right)$$

$$\sigma_x^A \cdot \sigma_x^B \cdot \sigma_x^C = -1 \qquad X_A\, X_B\, X_C = -1$$

$$\sigma_x^A \cdot \sigma_y^B \cdot \sigma_y^C = 1 \qquad X_A\, Y_B\, Y_C = 1$$

$$\sigma_y^A \cdot \sigma_x^B \cdot \sigma_y^C = 1 \qquad Y_A\, X_B\, Y_C = 1$$

$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1 \qquad Y_A\, Y_B\, X_C = 1$$

The GHZ Game Quantum Strategy

$$|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_A|\uparrow\rangle_B|\uparrow\rangle_C - |\downarrow\rangle_A|\downarrow\rangle_B|\downarrow\rangle_C\right)$$

$$\sigma_x^A \cdot \sigma_x^B \cdot \sigma_x^C = -1$$

$$\sigma_x^A \cdot \sigma_y^B \cdot \sigma_y^C = 1$$

$$\sigma_y^A \cdot \sigma_x^B \cdot \sigma_y^C = 1$$

$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1$$

X=?

B

$\sigma_x = -1$

X=?

A

$\sigma_x = -1$

X=?

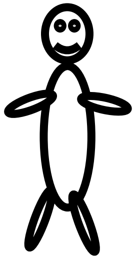
C

Miracle: change of a spin state by remote action

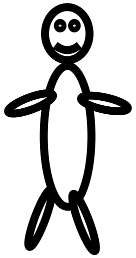
Teleportation

Teleportation

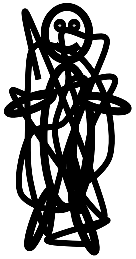
Teleportation



Science Fiction: **Matter cannot “jump” in space time**



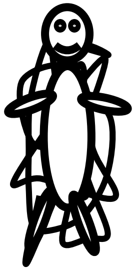
Teleportation



Science Fiction: **Matter cannot "jump" in space time**

Quantum mechanics: **We do not have to move matter**
All matter is the same. We need to move only the shape, the quantum wave function Ψ

$= \Psi$



Teleportation

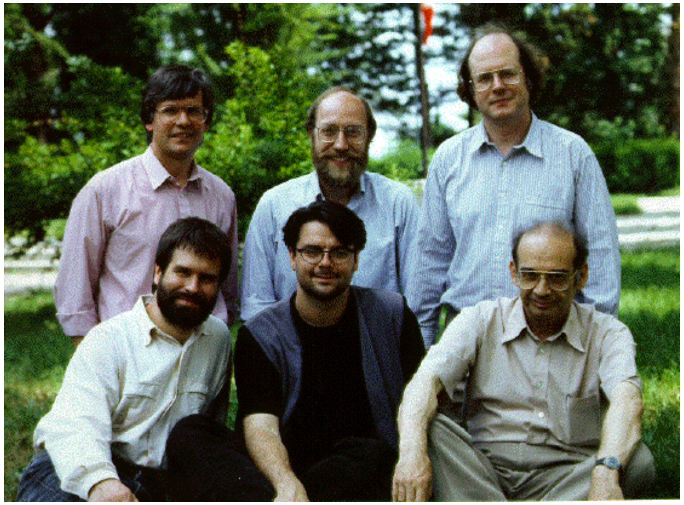
PHYSICAL REVIEW LETTERS

VOLUME 70 29 MARCH 1993 NUMBER 13

Teleporting an Unknown Quantum State via Dual Classical and Einstein-Podolsky-Rosen Channels

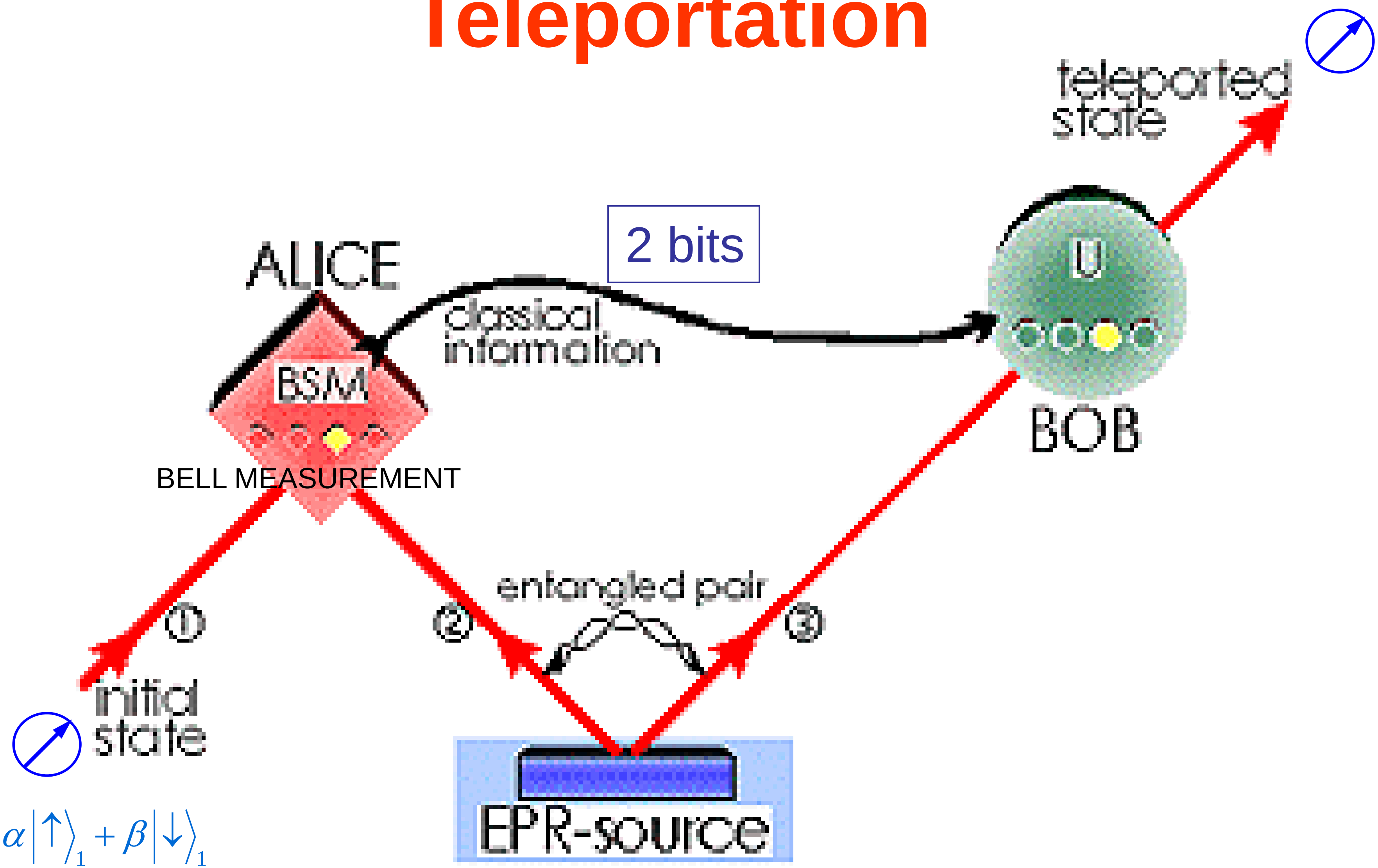
Charles H. Bennett,[1] Gilles Brassard,[2] Claude Crépeau,[2],[3] Richard Jozsa,[2] Asher Peres,[4] and William K. Wootters[5]

An unknown quantum state $|\phi\rangle$ can be disassembled into, then later reconstructed from, purely classical information and purely nonclassical Einstein-Podolsky-Rosen (EPR) correlations. To do so the sender, "Alice," and the receiver, "Bob," must prearrange the sharing of an EPR-correlated pair of particles. Alice makes a joint measurement on her EPR particle and the unknown quantum system, and sends Bob the classical result of this measurement. Knowing this, Bob can convert the state of his EPR particle into an exact replica of the unknown state $|\phi\rangle$ which Alice destroyed.



Teleportation

$$\alpha\left|\uparrow\right\rangle_3 + \beta\left|\downarrow\right\rangle_3$$

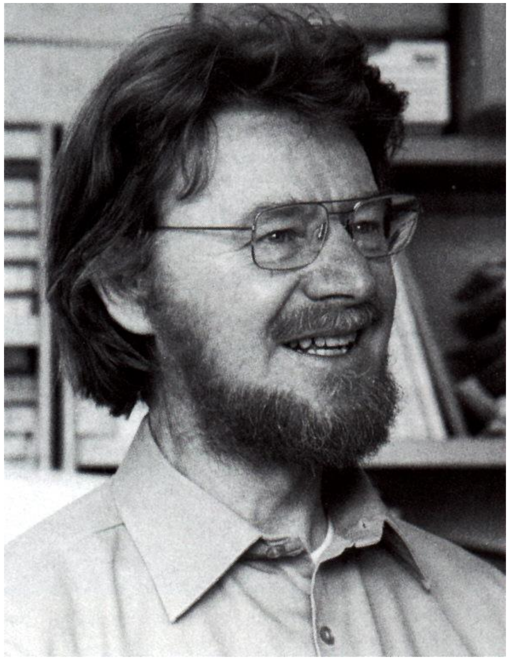


$$\alpha\left|\uparrow\right\rangle_1 + \beta\left|\downarrow\right\rangle_1$$

$$\frac{1}{\sqrt{2}}\left(\left|\uparrow\right\rangle_2\left|\downarrow\right\rangle_3 - \left|\downarrow\right\rangle_2\left|\uparrow\right\rangle_3\right)$$

Bell States

spin rotation

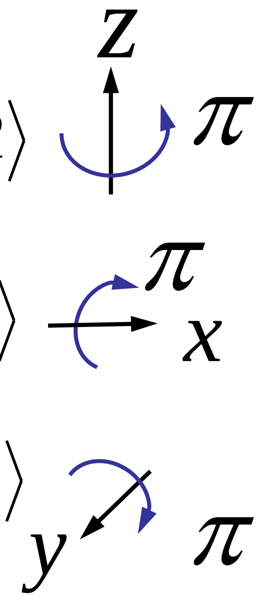


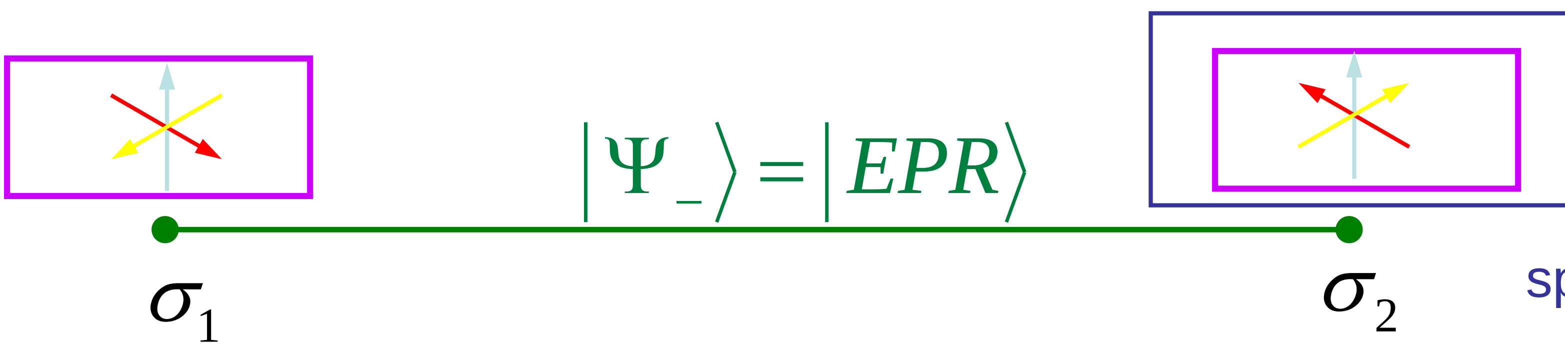
$$|\Psi_-\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2 - |\downarrow\rangle_1|\uparrow\rangle_2\right) = |EPR\rangle$$

$$|\Psi_+\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2 + |\downarrow\rangle_1|\uparrow\rangle_2\right) = |EPR\rangle$$

$$|\Phi_-\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2 - |\downarrow\rangle_1|\downarrow\rangle_2\right) = |EPR\rangle$$

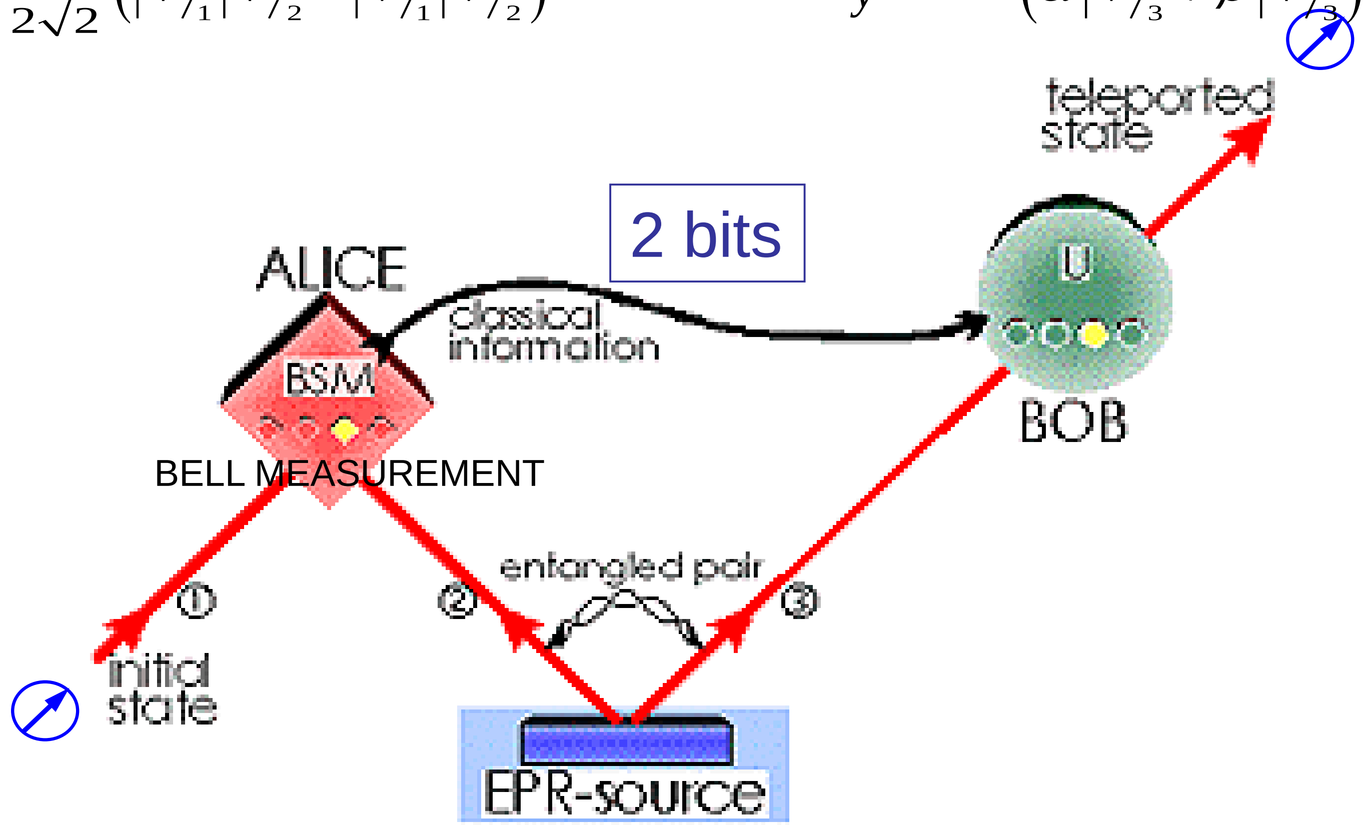
$$|\Phi_+\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2 + |\downarrow\rangle_1|\downarrow\rangle_2\right) = |EPR\rangle$$





spin rotation

$$
\begin{aligned}
|\Psi\rangle = \; & -\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2 - |\downarrow\rangle_1|\uparrow\rangle_2\right) && && \left(\alpha|\uparrow\rangle_3 + \beta|\downarrow\rangle_3\right) \\
& -\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2 + |\downarrow\rangle_1|\uparrow\rangle_2\right) && z\;\pi && \left(\alpha|\uparrow\rangle_3 - \beta|\downarrow\rangle_3\right) \\
& +\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2 + |\downarrow\rangle_1|\downarrow\rangle_2\right) && x\;\pi && \left(\alpha|\downarrow\rangle_3 - \beta|\uparrow\rangle_3\right) \\
& +\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2 - |\downarrow\rangle_1|\downarrow\rangle_2\right) && y\;\pi && \left(\alpha|\downarrow\rangle_3 + \beta|\uparrow\rangle_3\right)
\end{aligned}
$$



$$
|\Psi\rangle = \frac{1}{\sqrt{2}}\left(\alpha|\uparrow\rangle_1 + \beta|\downarrow\rangle_1\right) \qquad \left(|\uparrow\rangle_2|\downarrow\rangle_3 - |\downarrow\rangle_2|\uparrow\rangle_3\right)
$$

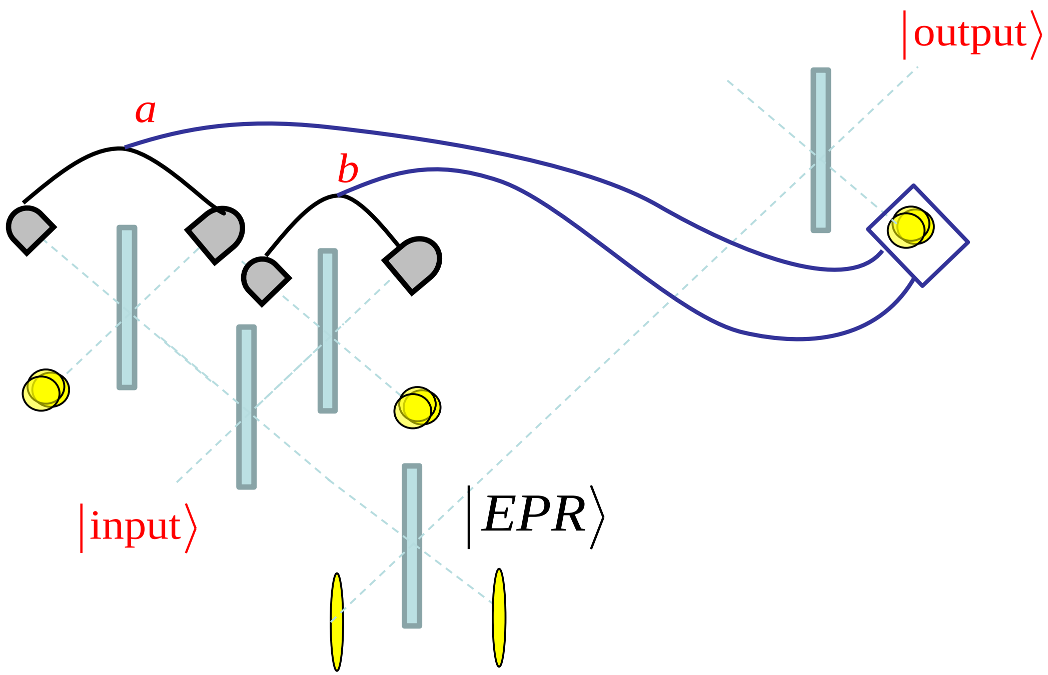
Continuous Variables Teleportation

PHYSICAL REVIEW A VOLUME 49, NUMBER 2 FEBRUARY 1994

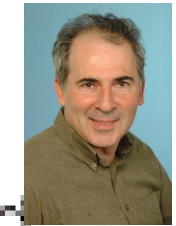
Teleportation of quantum states

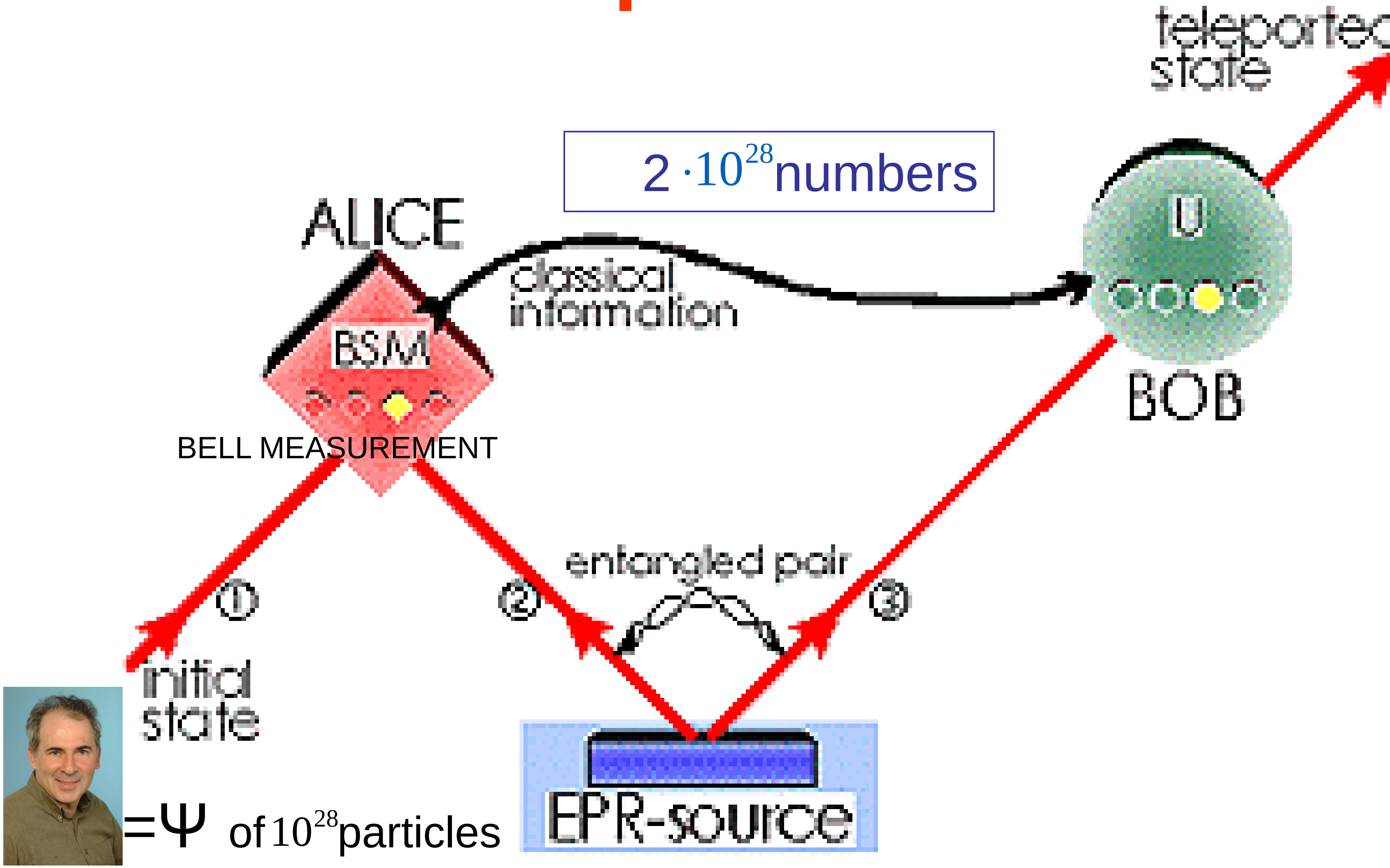
Lev Vaidman
School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel-Aviv University, Tel-Aviv, 69978, Israel
(Received 10 June 1993; revised manuscript received 7 July 1993)

The recent result of Bennett *et al.* [Phys. Rev. Lett. **70**, 1895 (1993)] of teleportation of an unknown quantum state is obtained in the framework of nonlocal measurements proposed by Aharonov and Albert [Phys. Rev. D **21**, 3316 (1980); **24**, 359 (1981)]. The latter method is generalized to the teleportation of a quantum state of a system with continuous variables.

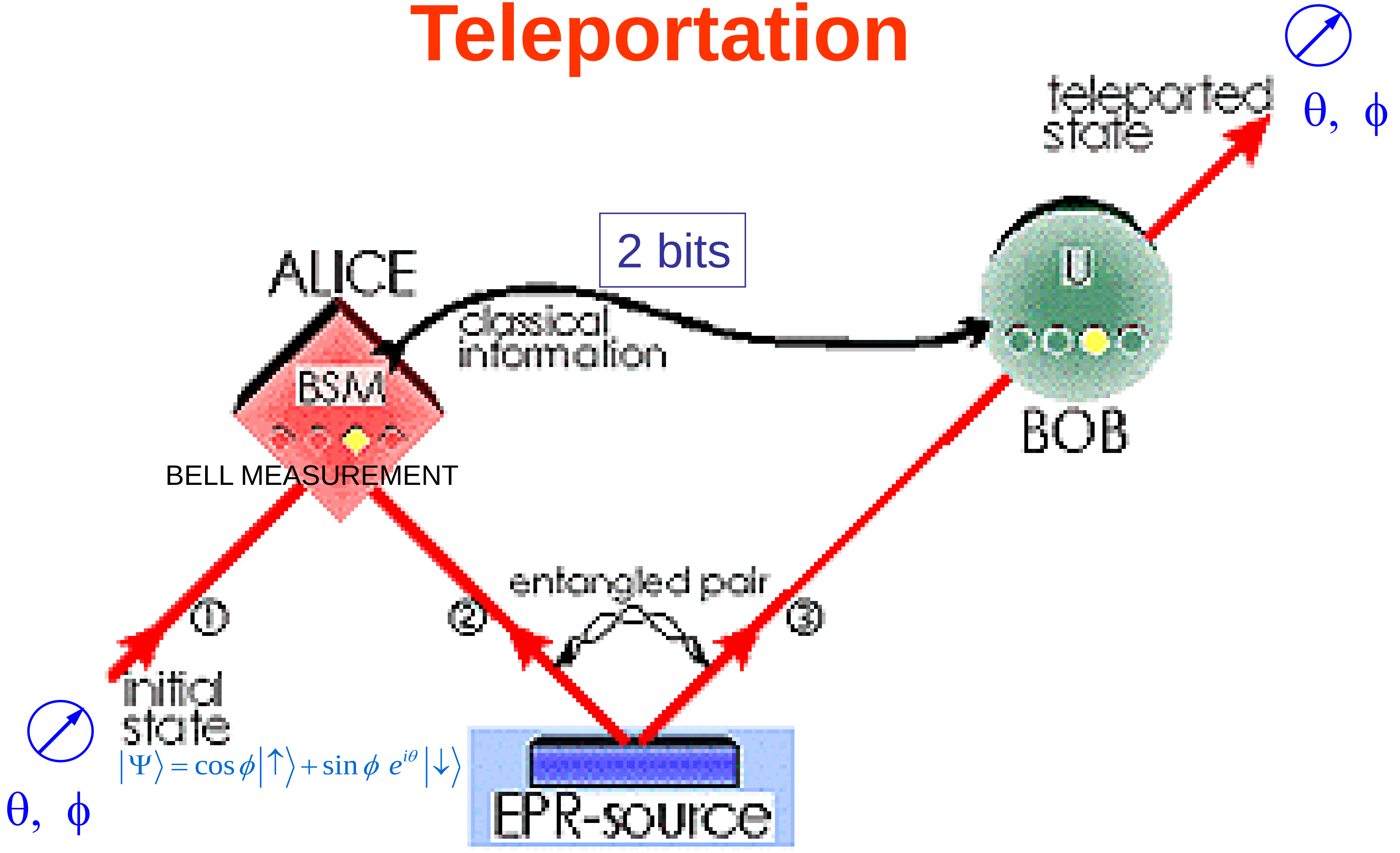


Teleportation





Teleportation



Miracle: sending 2 real numbers with just 2 bits

THE PARADOX OF THE INTERACTION-FREE MEASUREMENT

A. Elitzur and L. Vaidman
Found. Phys. **23**, 987 (1993) .

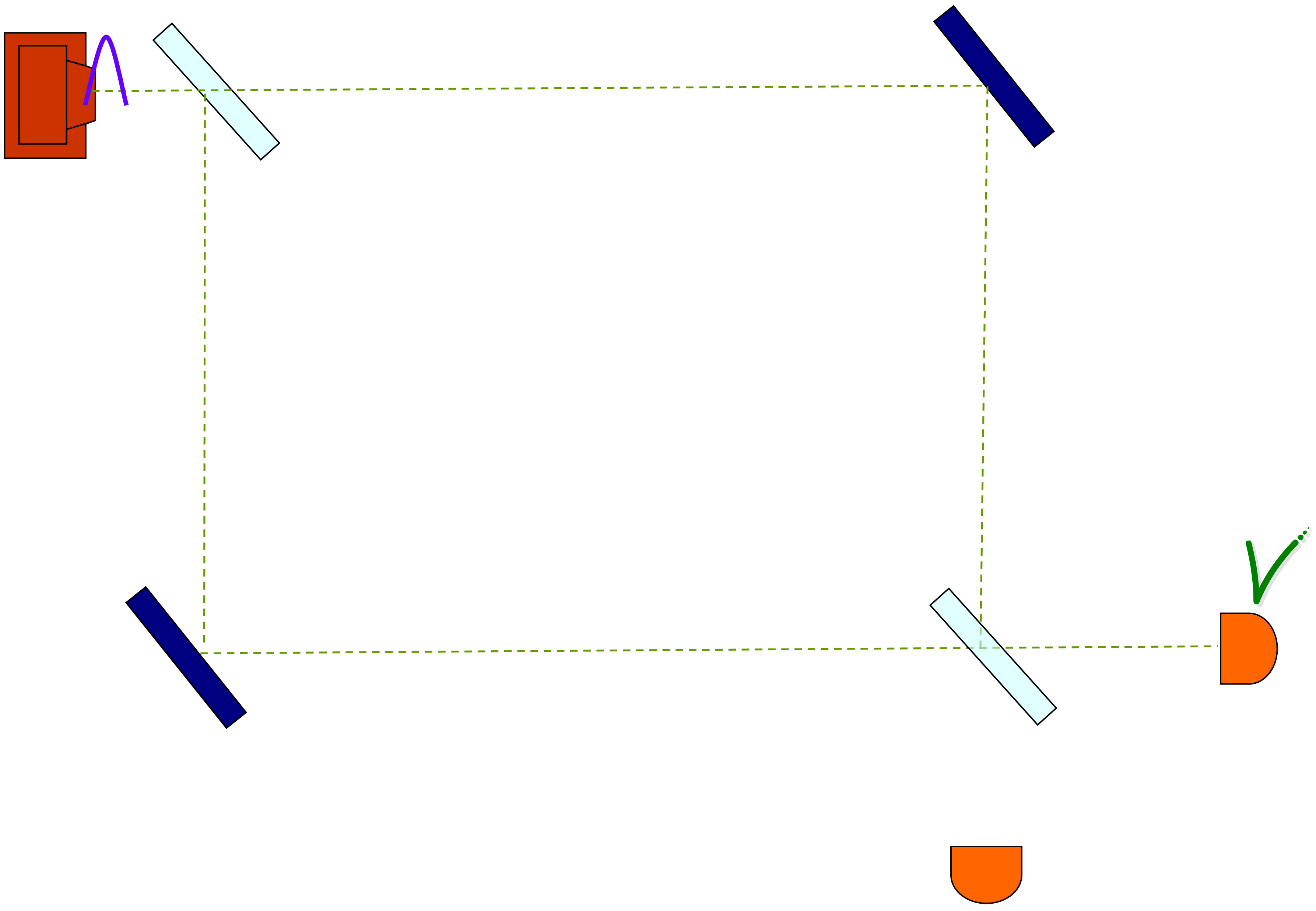
BOMB: explodes when any particle “touches” it

interacts only through explosion

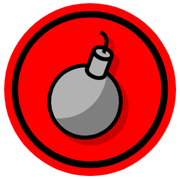
HOW TO FIND BOMB WITHOUT EXPLODING IT?

QUANTUM MECHANICS SOLVES THIS ⇨ PARADOX

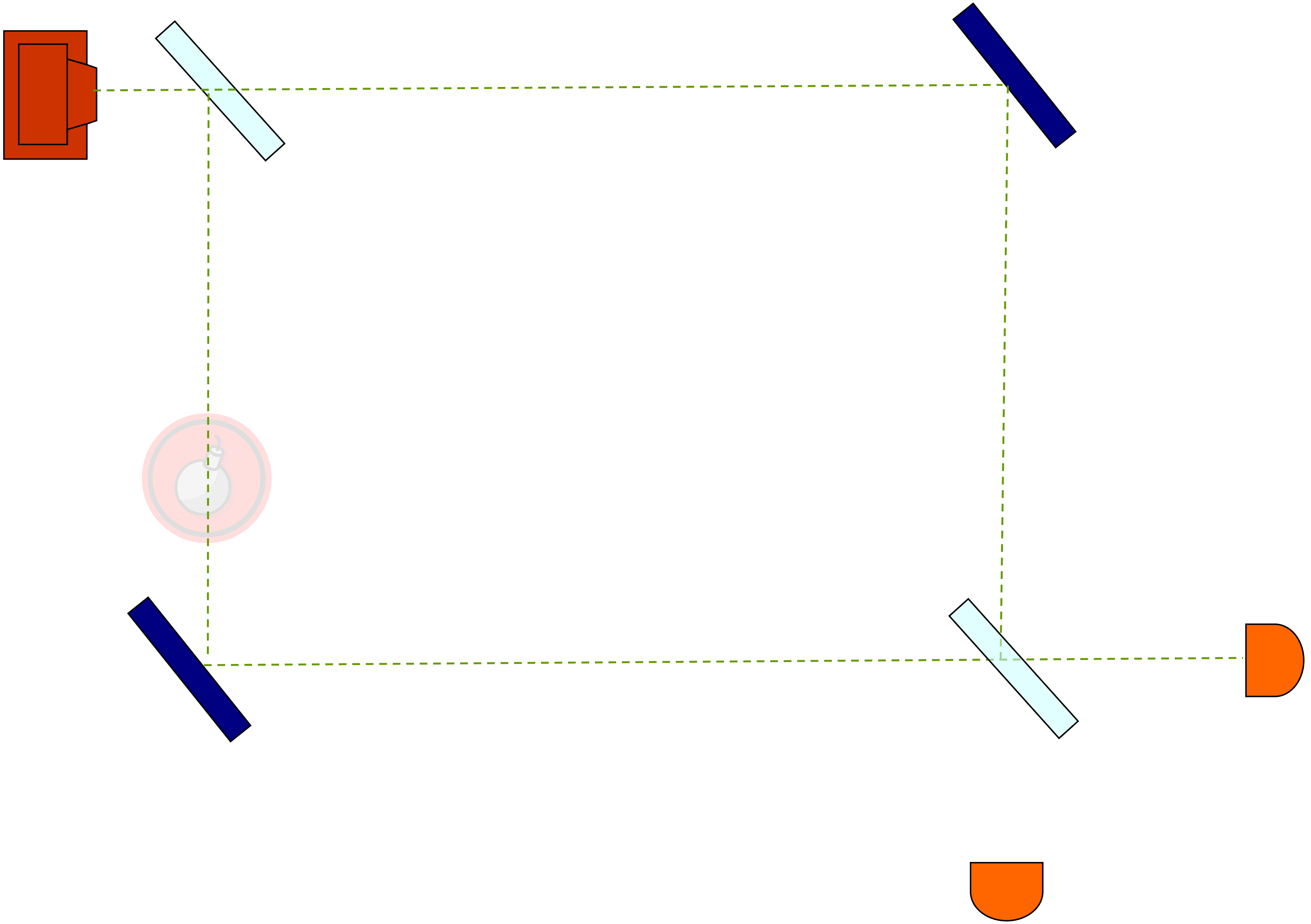
Interaction-free measurement



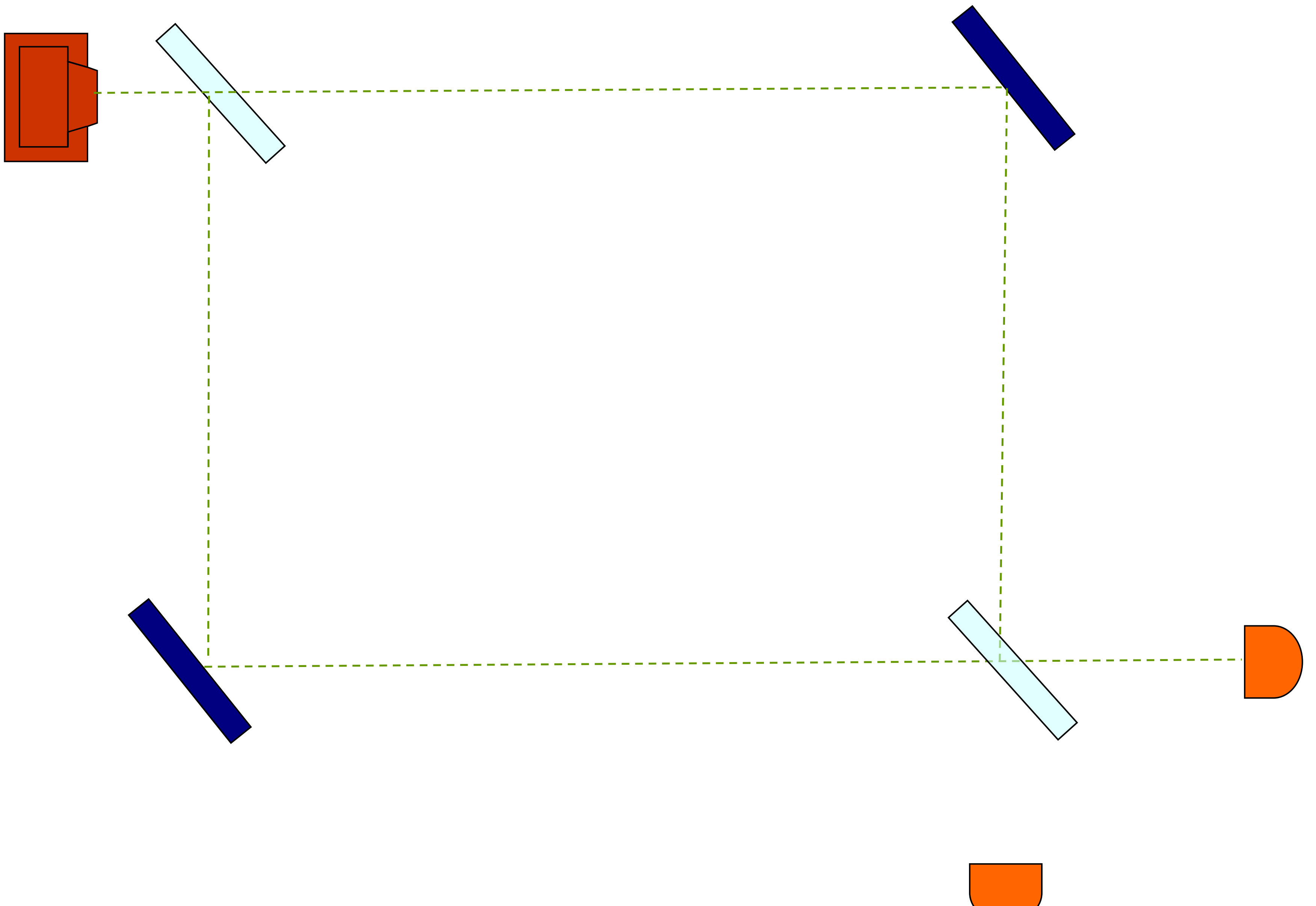
Interaction-free measurement



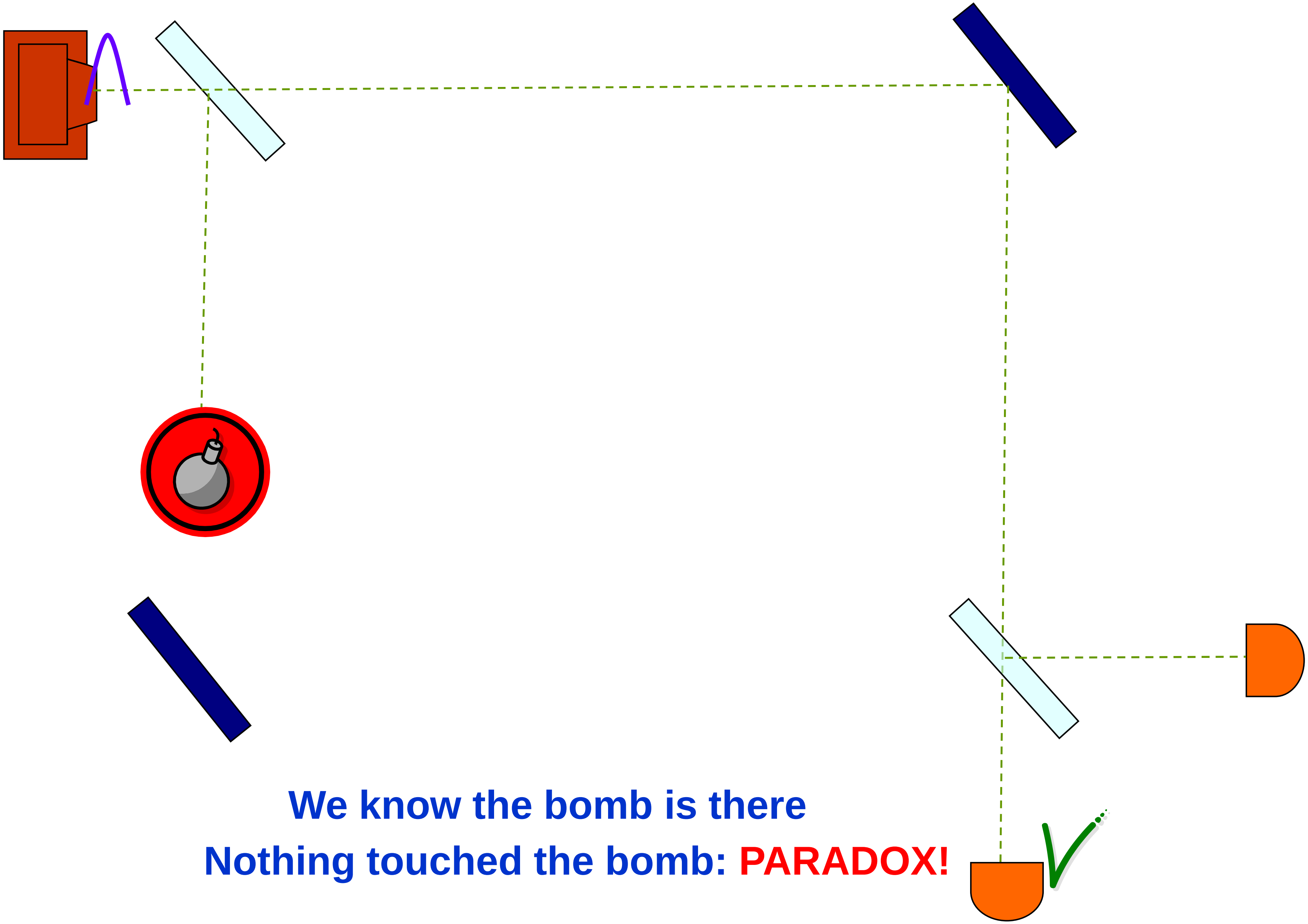
Interaction-free measurement



Interaction-free measurement



Interaction-free measurement



We know the bomb is there

Nothing touched the bomb: PARADOX!

MWI

plato.stanford.edu/entries/qm-manyworlds/

I. The fundamental ontology:
All is Ψ evolving according to the relativistic generalization of the Schrodinger equation

II. The connection between ontology and experience:
There are multiple worlds similar to the one we experience.

The experience of an observer in a world is completely specified by the textbook (collapsing) wave function Ψ_{WORLD} .

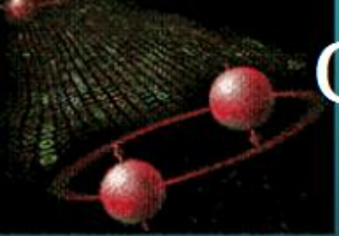
Quantum states of all macroscopic objects are Localized Wave Packets

Alternatively, Ψ_{WORLD} is defined by

BORN-VAIDMAN RULE:
The probability of self-location of an observer in a particular world is proportional to its measure of existence

$$|\Psi\rangle = \sum_i \alpha_i |\Psi_{WORLD\,i}\rangle$$

$$\mu_{WORLD\,i} = |\langle \Psi_{WORLD\,i} | \Psi \rangle|^2 = |\alpha_i|^2$$



Quantum Optics Lab

The Quantum World Splitter

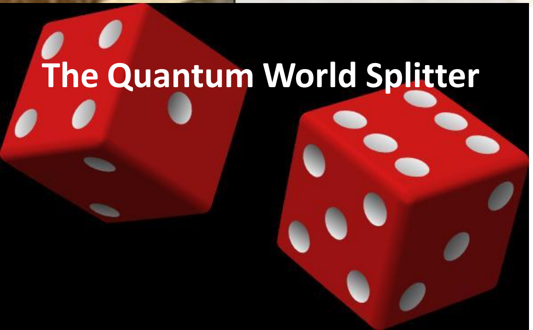
ome MWI Split

http://qol.tau.ac.il/TWS.html

Welcome To The Quantum World Splitter

You now have a control over a Quantum Optics Laboratory In Tel Aviv University.
When you push SPLIT you will preform a quantum experiment with single photons.
You can choose from splitting 2 up to 6 worlds, they will be created with a copy of you in each world.

If you want to choose between several options in your life, now you can do them all at once.

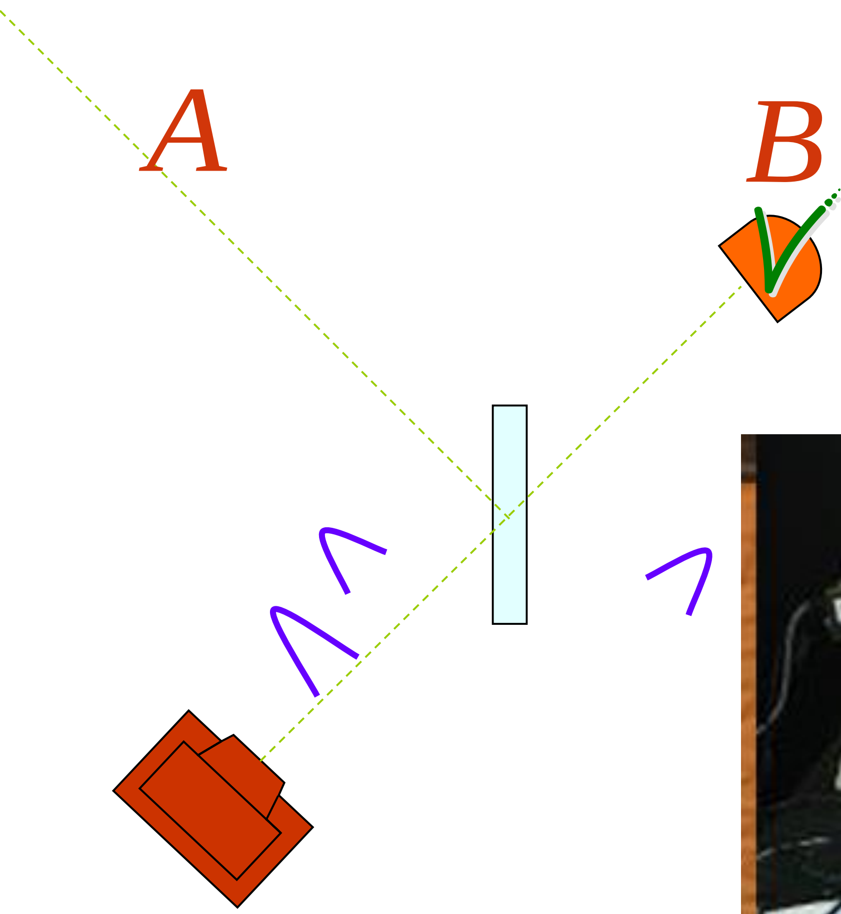


Choose how many worlds you want to split by pressing one of the red dice faces.

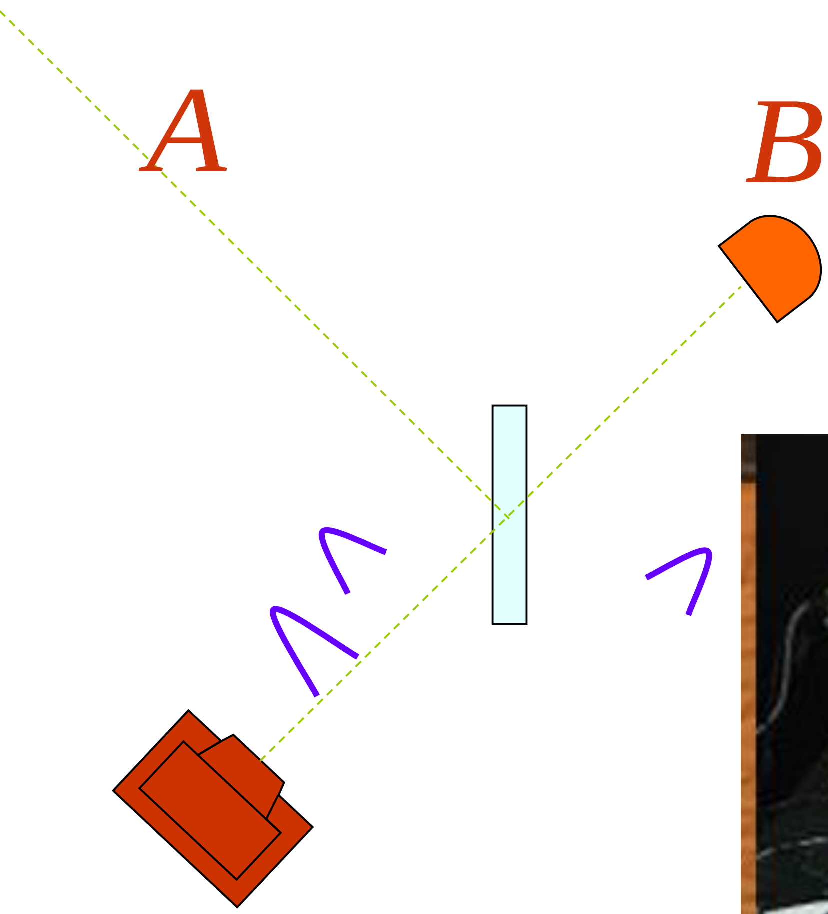

Quantum Optics Lab
The Quantum World Splitter
Welcome
Split
http://qol.tau.ac.il/TWS.html
Please enter your options
left
right
Split


Quantum Optics Lab
The Quantum World Splitter
Welcome
Split
http://qol.tau.ac.il/TWS.html
You are in right World
Click here to for additional splitting

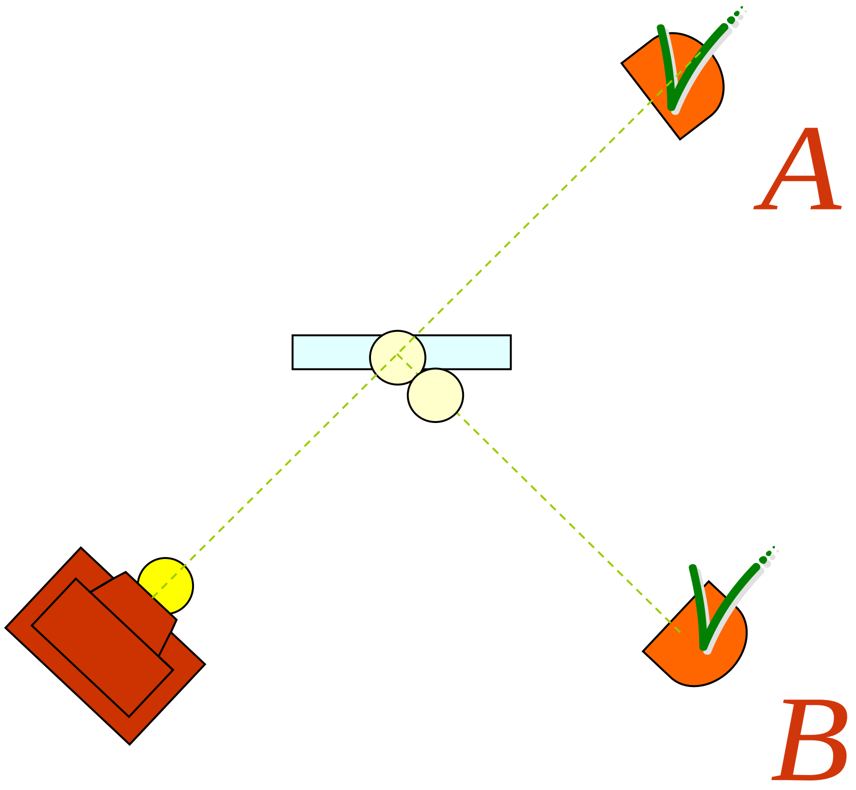
World-splitter of Tel Aviv University



World-splitter of Tel Aviv University

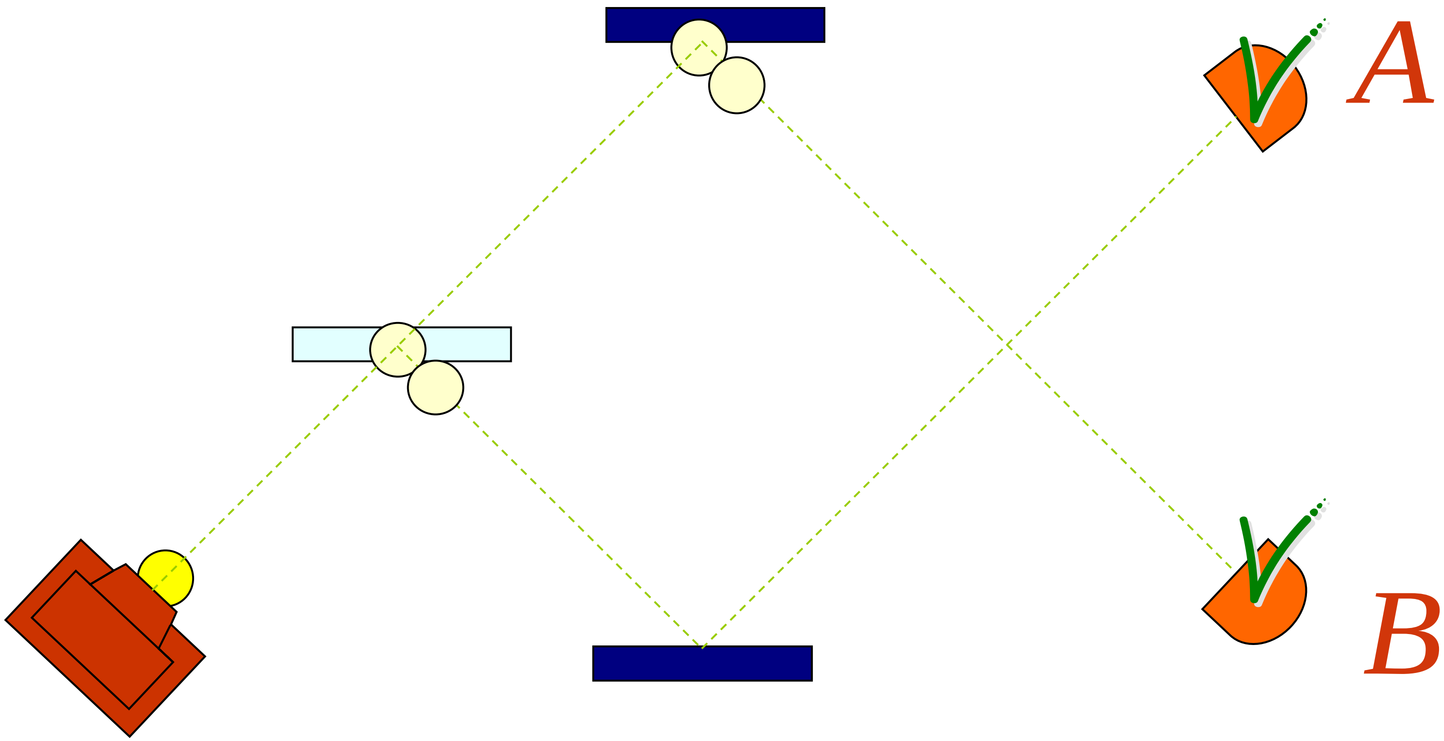


Two worlds universe



Two worlds universe

One world does not disturb the other



Two worlds universe

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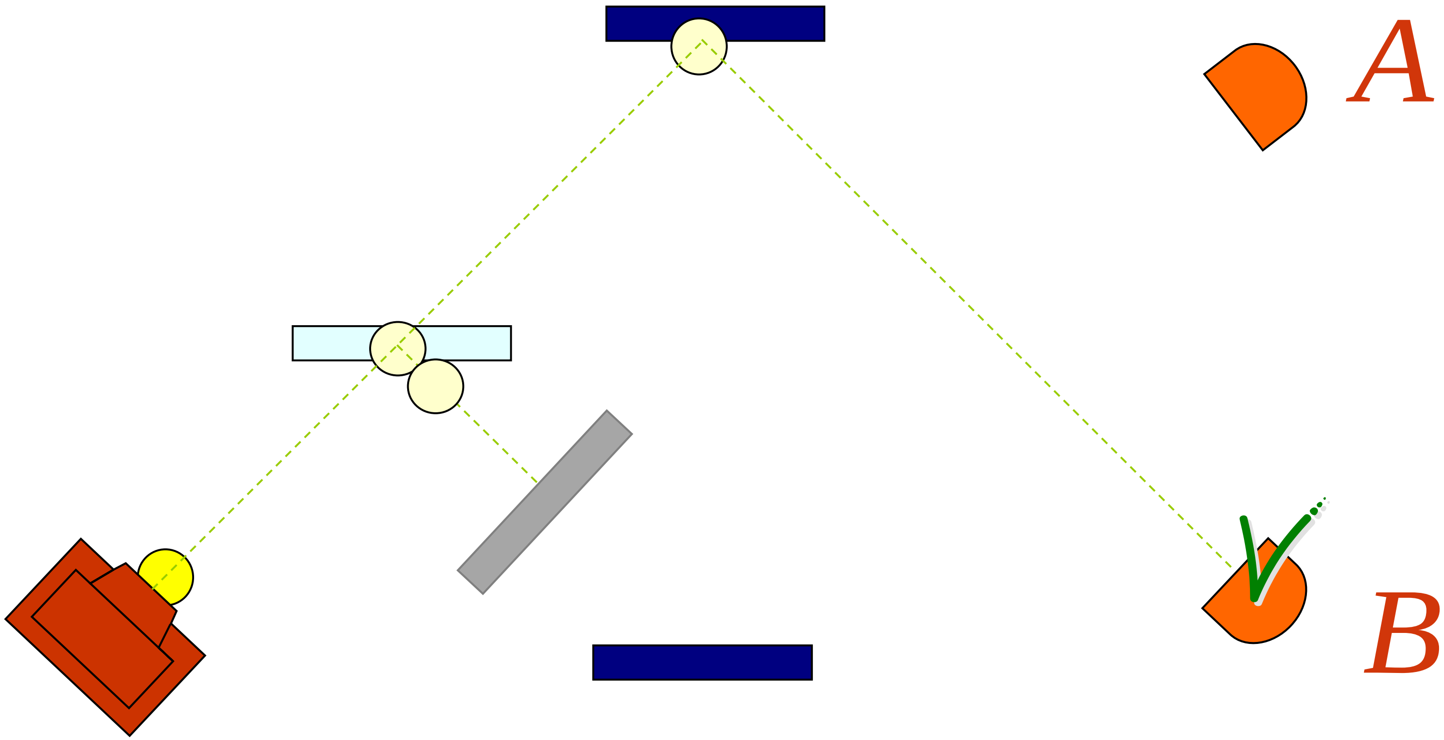
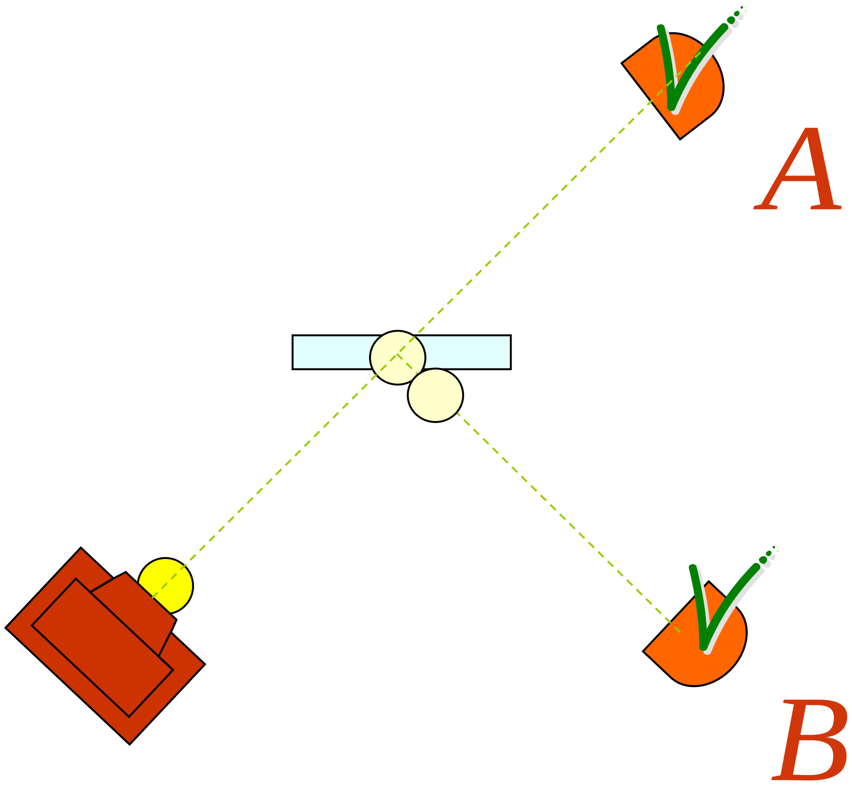
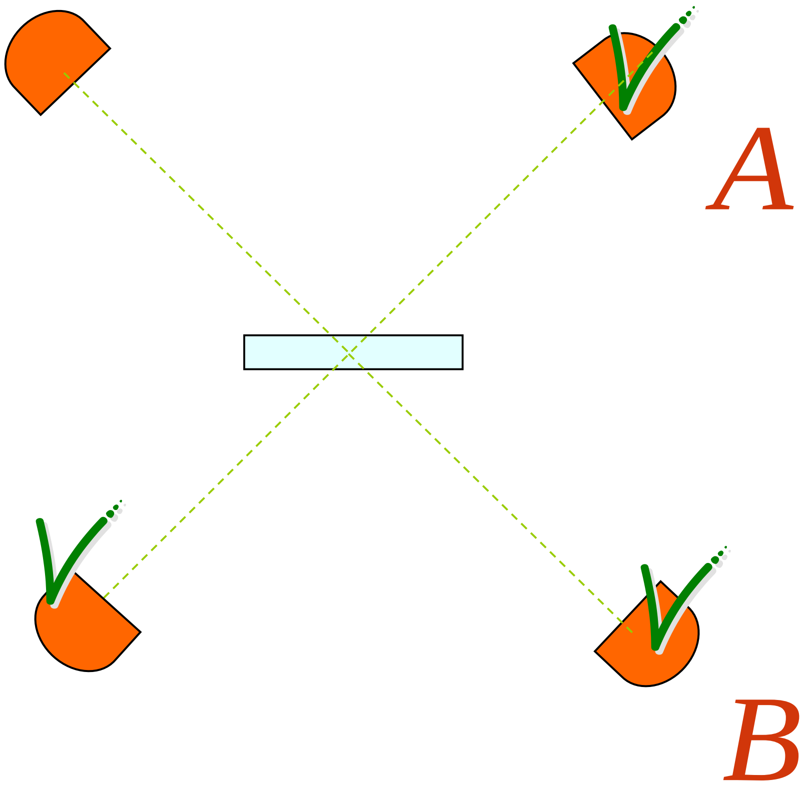


Test of the MWI



Test of the MWI



The GHZ Game Quantum Strategy

$$|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_A |\uparrow\rangle_B |\uparrow\rangle_C - |\downarrow\rangle_A |\downarrow\rangle_B |\downarrow\rangle_C\right)$$

$$\sigma_x^A \cdot \sigma_x^B \cdot \sigma_x^C = -1$$

$$\sigma_x^A \cdot \sigma_y^B \cdot \sigma_y^C = 1$$

$$\sigma_y^A \cdot \sigma_x^B \cdot \sigma_y^C = 1$$

$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1$$

X=?

B

$\sigma_x = -1$

A

$\sigma_x = -1$

X=?

X=?

C

Miracle: change of a spin state by remote action

The GHZ Game Quantum Strategy

$$|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_A |\uparrow\rangle_B |\uparrow\rangle_C - |\downarrow\rangle_A |\downarrow\rangle_B |\downarrow\rangle_C\right)$$

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$$\sigma_y^A \cdot \sigma_x^B \cdot \sigma_y^C = 1$$

$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1$$

X=?

B

$\sigma_x = -1$

A

$\sigma_x = +1$

X=?

X=?

C

Miracle: change of a spin state by remote action

The GHZ Game: the universe picture

$$|GHZ\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_A |\uparrow\rangle_B |\uparrow\rangle_C - |\downarrow\rangle_A |\downarrow\rangle_B |\downarrow\rangle_C\right)$$

$$\sigma_x^A \cdot \sigma_x^B \cdot \sigma_x^C = -1$$

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$$\sigma_y^A \cdot \sigma_x^B \cdot \sigma_y^C = 1$$

$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1$$

X=?

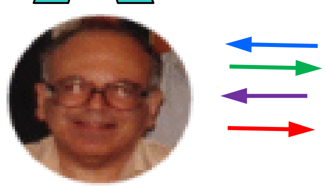
B

$\sigma_x = \pm 1$

X=?

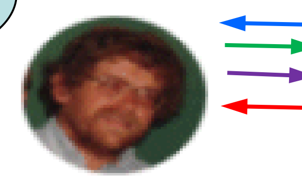
A

$\sigma_x = \pm 1$



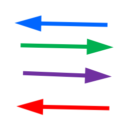
X=?

C

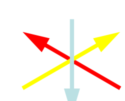


Miracle: change of a spin state by remote action

No miracle: no change of the remote spin



=



The GHZ Game: the universe picture

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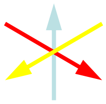
$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1$$

X=?

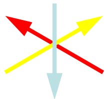
B



BEFORE

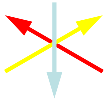
X=?

A



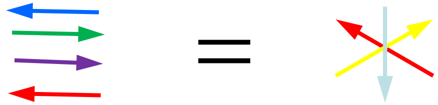
X=?

C



Miracle: change of a spin state by remote action

No miracle: no change of the remote spin



The GHZ Game: the universe picture

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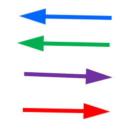
$$\sigma_y^A \cdot \sigma_y^B \cdot \sigma_x^C = 1$$

X=?

B

$\sigma_x = \pm 1$

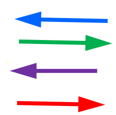


AFTER

X=?

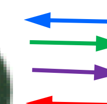
A

$\sigma_x = \pm 1$



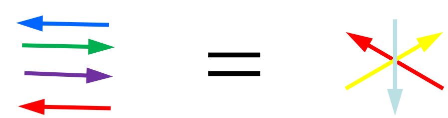
X=?

C



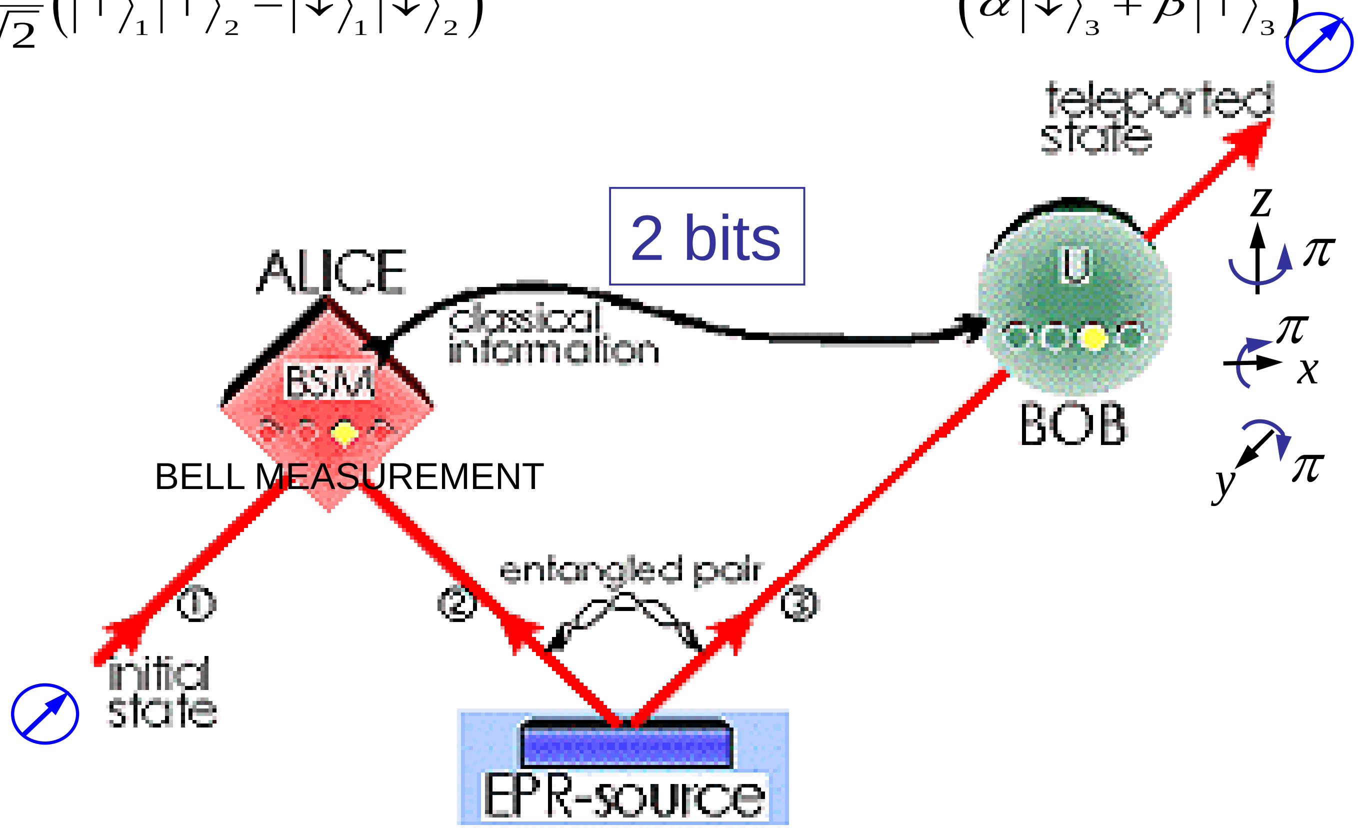
Miracle: change of a spin state by remote action

No miracle: no change of the remote spin



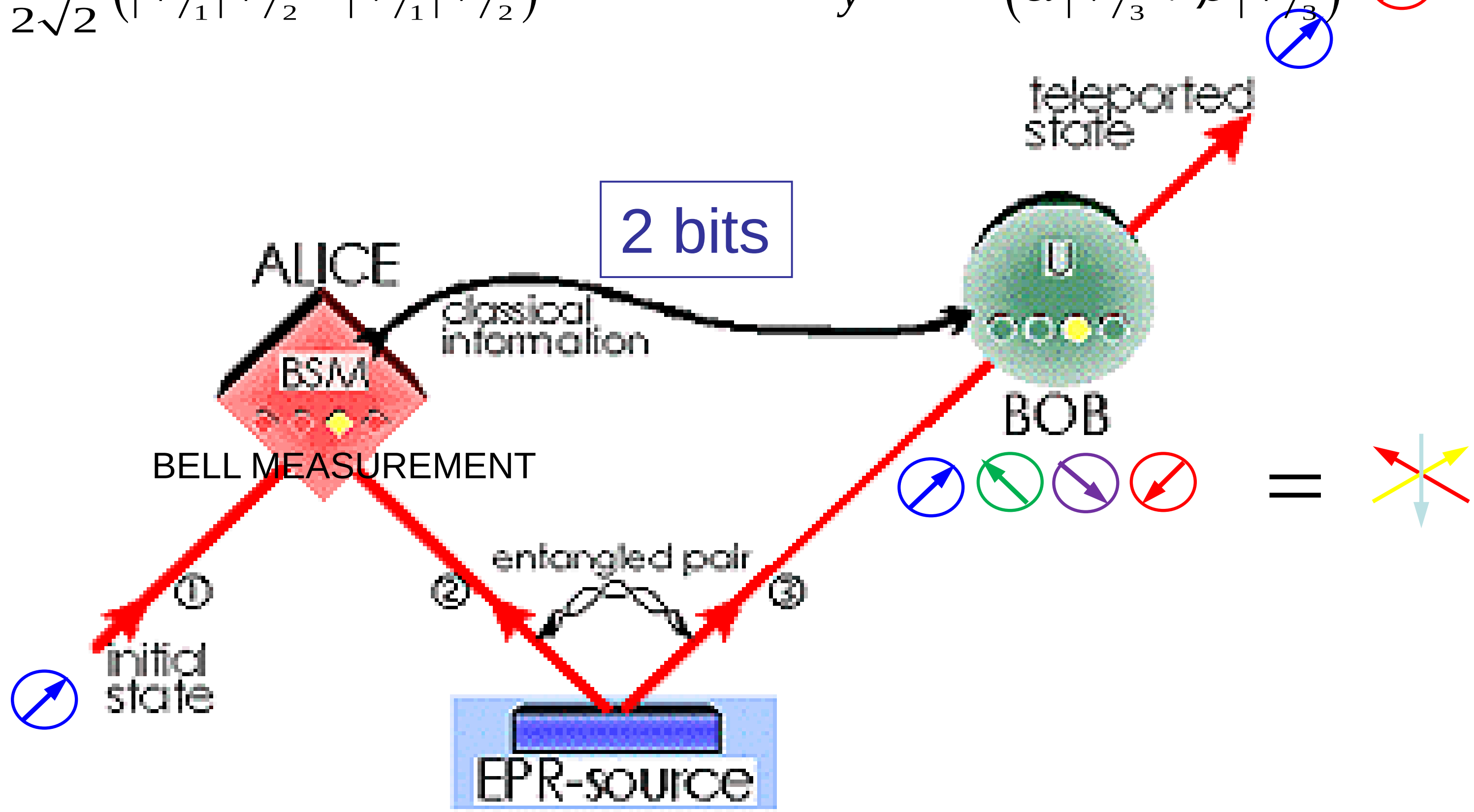
Teleportation

$$
\begin{aligned}
|\Psi\rangle = & -\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2 - |\downarrow\rangle_1|\uparrow\rangle_2\right) && \left(\alpha|\uparrow\rangle_3 + \beta|\downarrow\rangle_3\right) \\
& -\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2 + |\downarrow\rangle_1|\uparrow\rangle_2\right) && \left(\alpha|\uparrow\rangle_3 - \beta|\downarrow\rangle_3\right) \\
& +\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2 + |\downarrow\rangle_1|\downarrow\rangle_2\right) && \left(\alpha|\downarrow\rangle_3 - \beta|\uparrow\rangle_3\right) \\
& +\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2 - |\downarrow\rangle_1|\downarrow\rangle_2\right) && \left(\alpha|\downarrow\rangle_3 + \beta|\uparrow\rangle_3\right)
\end{aligned}
$$



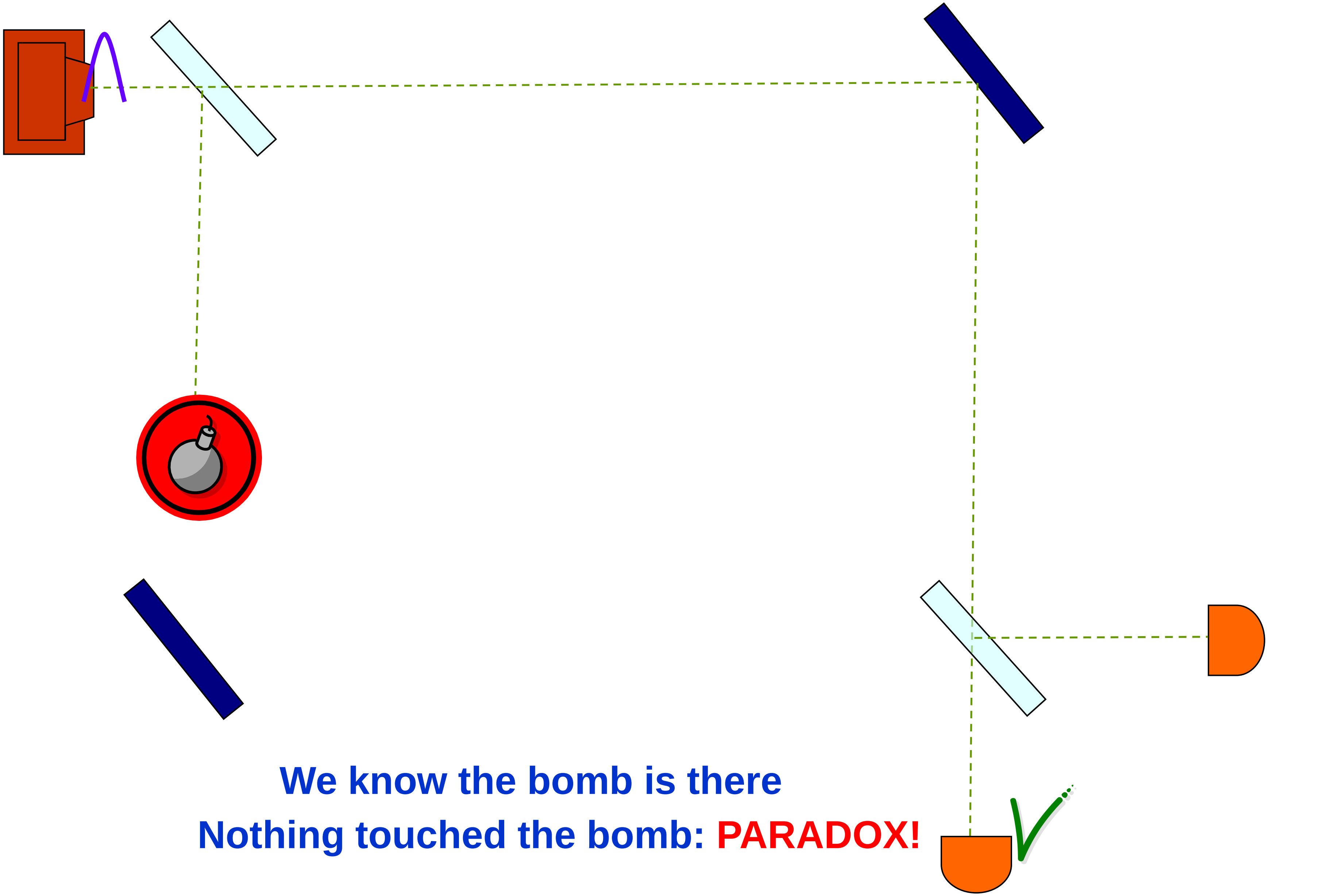
$$
|\Psi\rangle = \frac{1}{\sqrt{2}}\left(\alpha|\uparrow\rangle_1 + \beta|\downarrow\rangle_1\right) \left(|\uparrow\rangle_2|\downarrow\rangle_3 - |\downarrow\rangle_2|\uparrow\rangle_3\right)
$$

$$
\begin{aligned}
|\Psi\rangle = &-\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2-|\downarrow\rangle_1|\uparrow\rangle_2\right) && \left(\alpha|\uparrow\rangle_3+\beta|\downarrow\rangle_3\right)\\
&-\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\downarrow\rangle_2+|\downarrow\rangle_1|\uparrow\rangle_2\right) && z\ \pi \quad \left(\alpha|\uparrow\rangle_3-\beta|\downarrow\rangle_3\right)\\
&+\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2+|\downarrow\rangle_1|\downarrow\rangle_2\right) && x\ \pi \quad \left(\alpha|\downarrow\rangle_3-\beta|\uparrow\rangle_3\right)\\
&+\frac{1}{2\sqrt{2}}\left(|\uparrow\rangle_1|\uparrow\rangle_2-|\downarrow\rangle_1|\downarrow\rangle_2\right) && y\ \pi \quad \left(\alpha|\downarrow\rangle_3+\beta|\uparrow\rangle_3\right)
\end{aligned}
$$



$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(\alpha|\uparrow\rangle_1+\beta|\downarrow\rangle_1\right) \qquad \left(|\uparrow\rangle_2|\downarrow\rangle_3-|\downarrow\rangle_2|\uparrow\rangle_3\right)$$

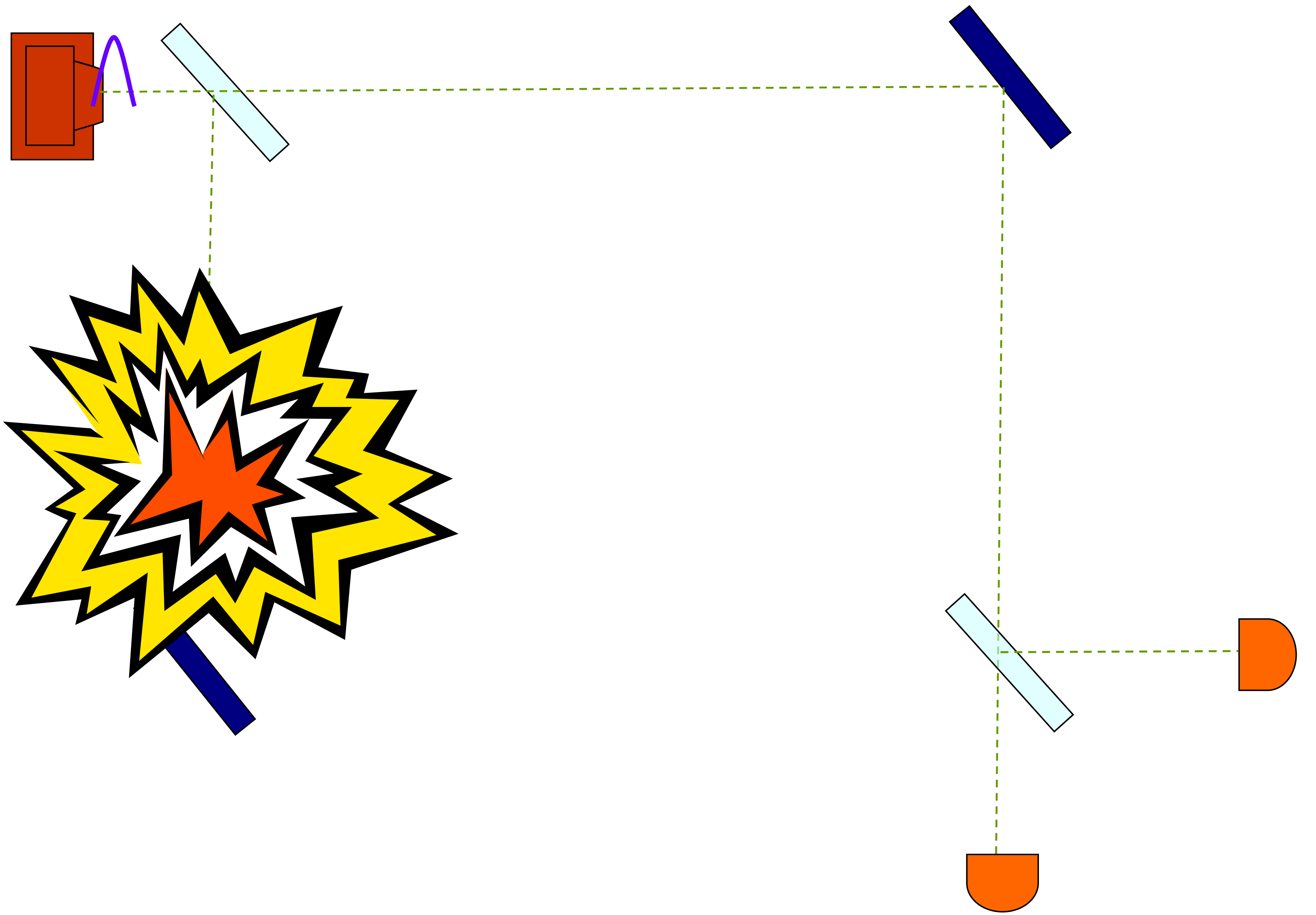
Interaction-free measurement



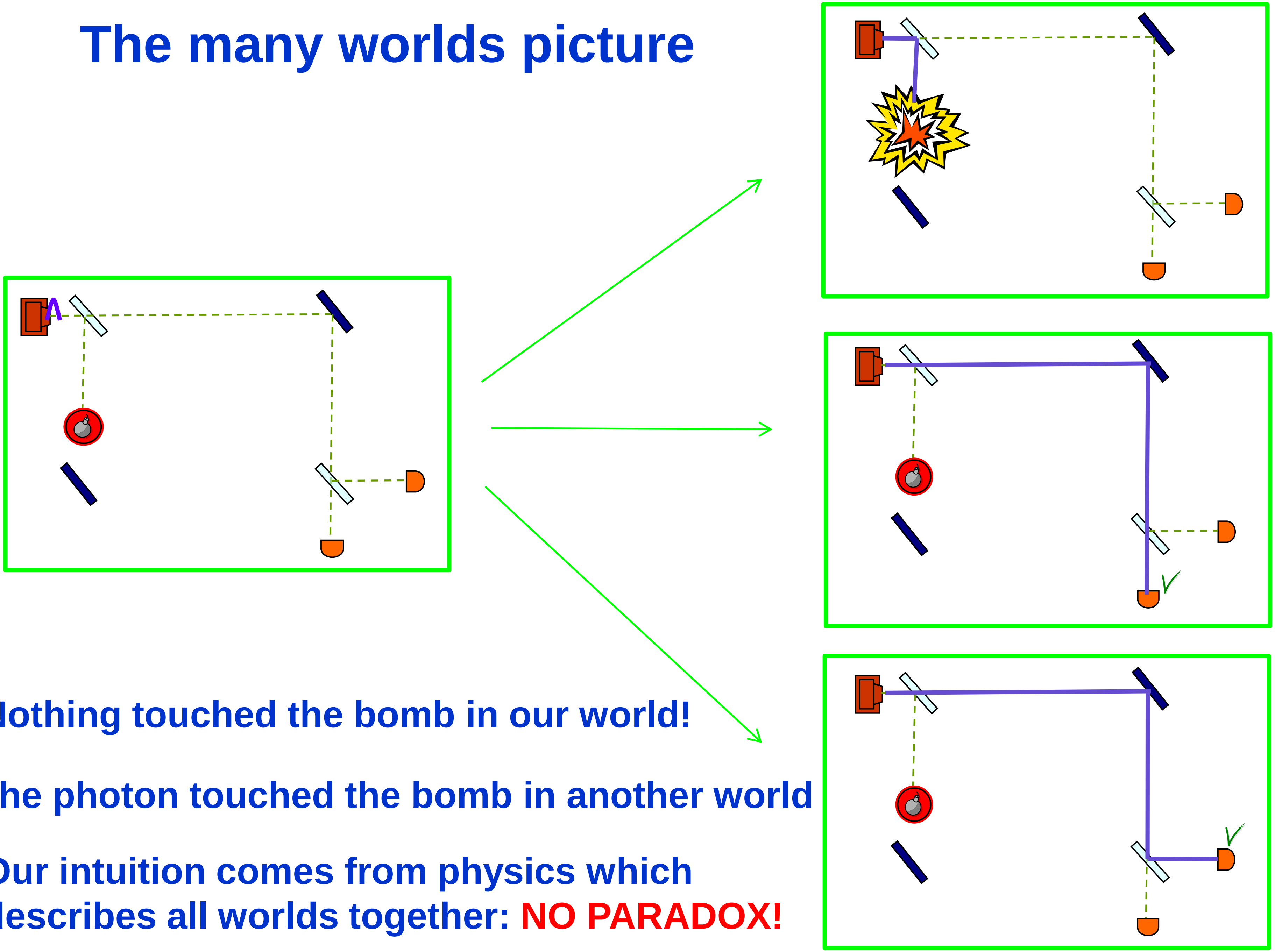
We know the bomb is there

Nothing touched the bomb: PARADOX!

Interaction-free measurement



The many worlds picture



Nothing touched the bomb in our world!

The photon touched the bomb in another world

Our intuition comes from physics which describes all worlds together: NO PARADOX!

Conclusions

Bell theorem (GHZ): The nature is apparently random and it has some kind of action at a distance

Teleportation transfers huge amount of (unreadable) information using a few bits

IFM provides information about presence of an object in a particular location without any particle being there

The MWI removes randomness and action at a distance from physics explaining why we have an illusion of randomness and Bell nonlocality