



## Manipolare i quanti di luce: verso la tecnologia del futuro



*Fabio Sciarrino*

Dipartimento di Fisica,  
“Sapienza” Università di Roma



<http://quantumoptics.phys.uniroma1.it>  
[www.3dquest.eu](http://www.3dquest.eu)



*..ora facciamo un salto nel passato...*



Home



vyomZTIXNDMT...



La scienza narrata ha ritwittato



**Henri** @Hennylechill

23/01/15

Probably the most intelligent #photo ever taken: 17/29 attendees became @NobelPrize winners #Einstein #Bohr #Curie



# Gli “anni d'oro” della Meccanica Quantistica: Conferenza di Solvay (1927)



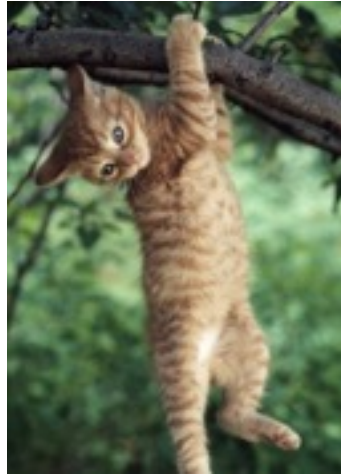
SOLVAY CONFERENCE 1927

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|             |            |              |              |               |                |                 |               |                 |             |              |
|-------------|------------|--------------|--------------|---------------|----------------|-----------------|---------------|-----------------|-------------|--------------|
| A. PICARD   | E. HENRIOT | P. EHRENFEST | Ed. HERSEN   | Th. DE DONDER | E. SCHRÖDINGER | E. VERSCHAFFELT | W. PAULI      | W. HEISENBERG   | R.H. FOWLER | L. BRILLOUIN |
| P. DEBYE    | M. KNUDSEN | W.L. BRAGG   | H.A. KRAMERS | P.A.M. DIRAC  | A.H. COMPTON   | L. de BROGLIE   | M. BORN       | N. BOHR         |             |              |
| I. LANGMUIR | M. PLANCK  | Mme CURIE    | H.A. LORENTZ | A. EINSTEIN   | P. LANGEVIN    | Ch.E. GUYE      | C.T.R. WILSON | O.W. RICHARDSON |             |              |

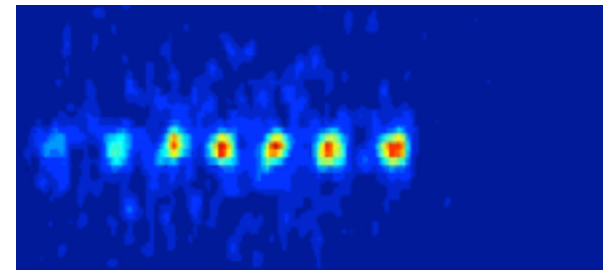
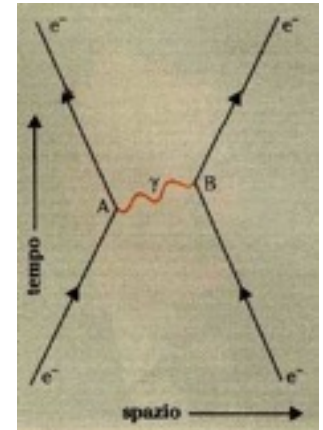
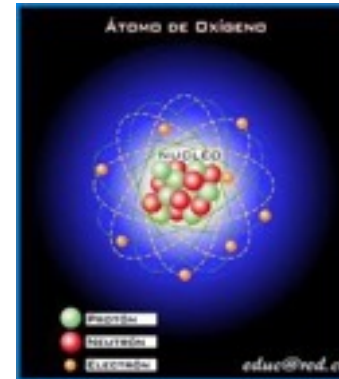
**Fisica dei quanti: Planck, Einstein, Bohr,  
Dirac, Schroedinger, Heisenberg, Pauli,...**

# MONDO MACROSCOPICO



# FISICA CLASSICA

# MONDO MICROSCOPICO



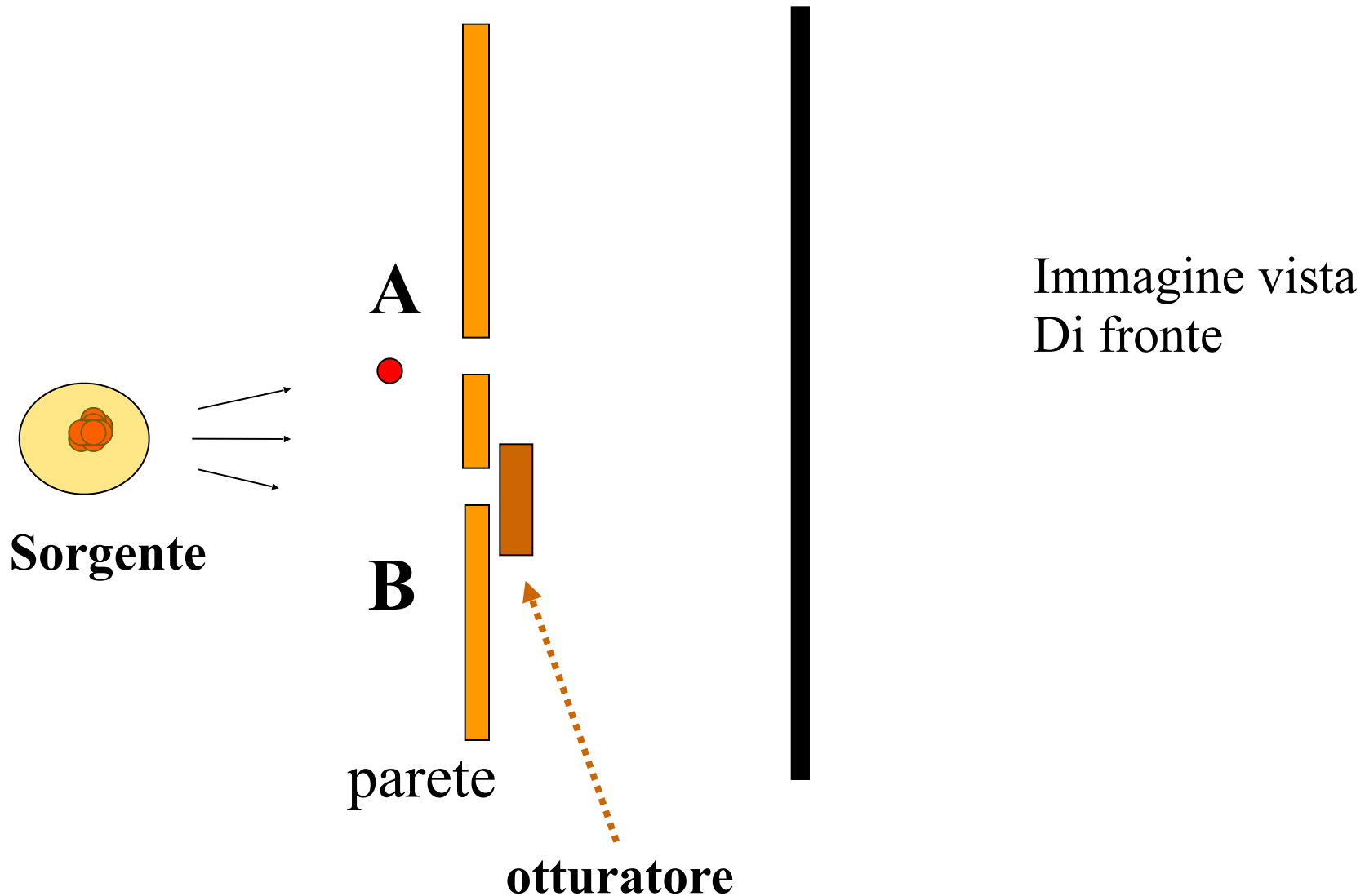
# FISICA QUANTISTICA

# L'interferenza

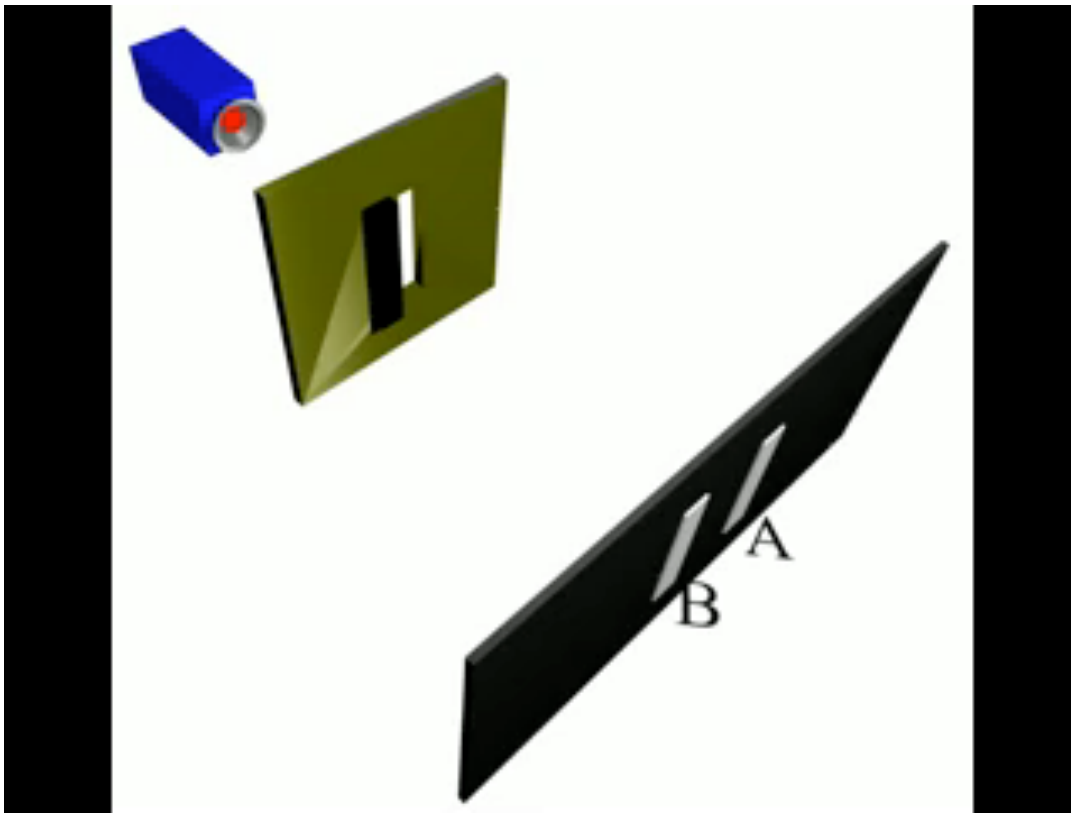
*“...the heart of quantum mechanics.  
In reality it contains the only mystery ...”  
R.P. Feynman (1965)*

***PRINCIPIO DI SOVRAPPOSIZIONE***

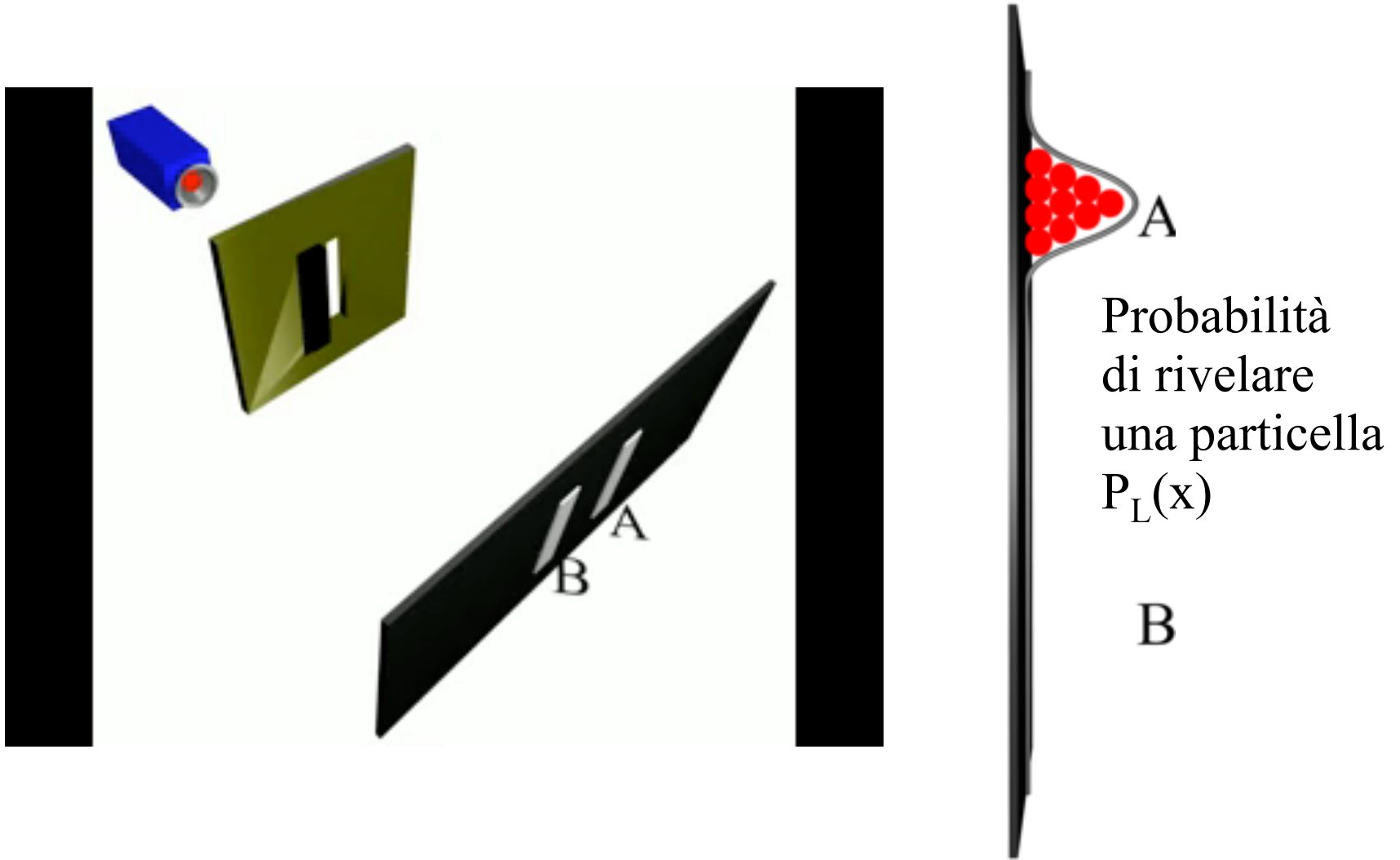
# Interferenza a singola particella



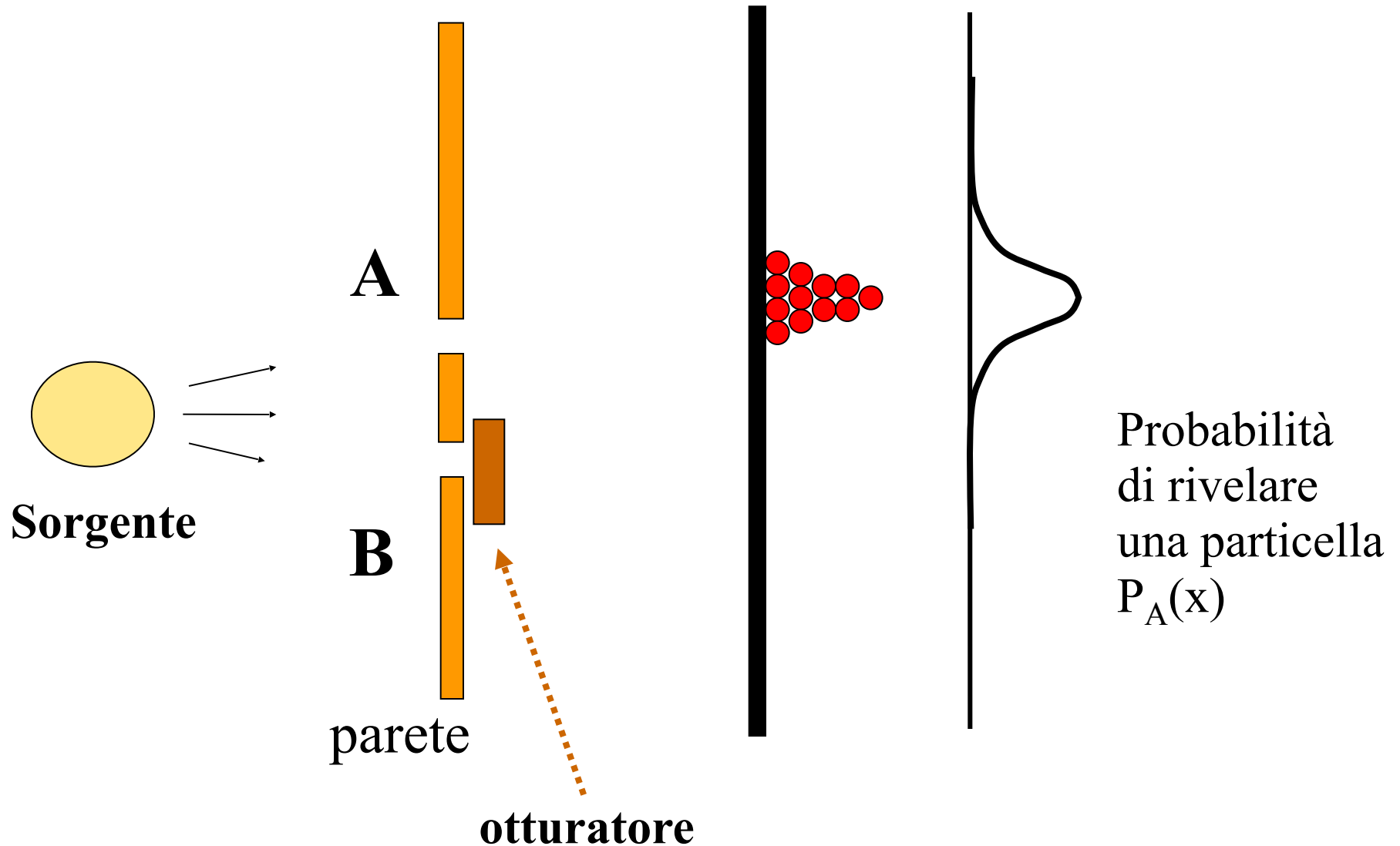
# Interferenza a singola particella



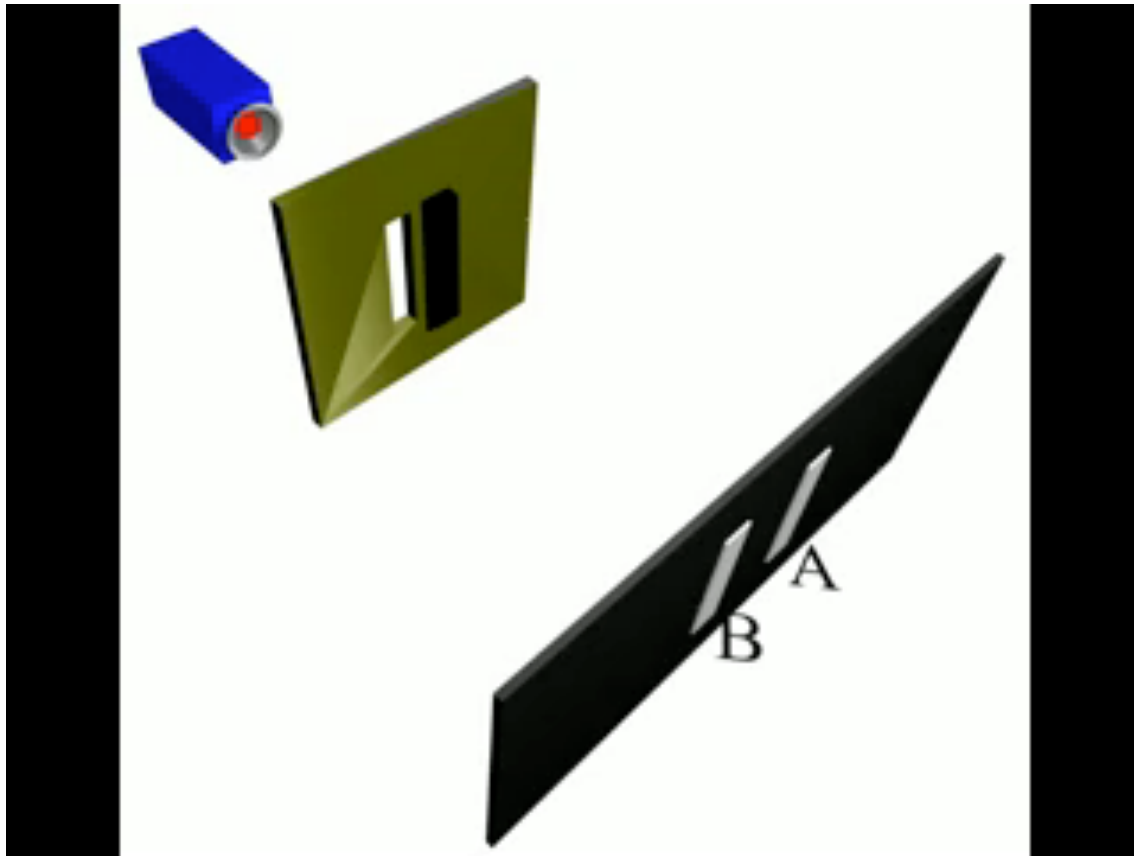
# Interferenza a singola particella



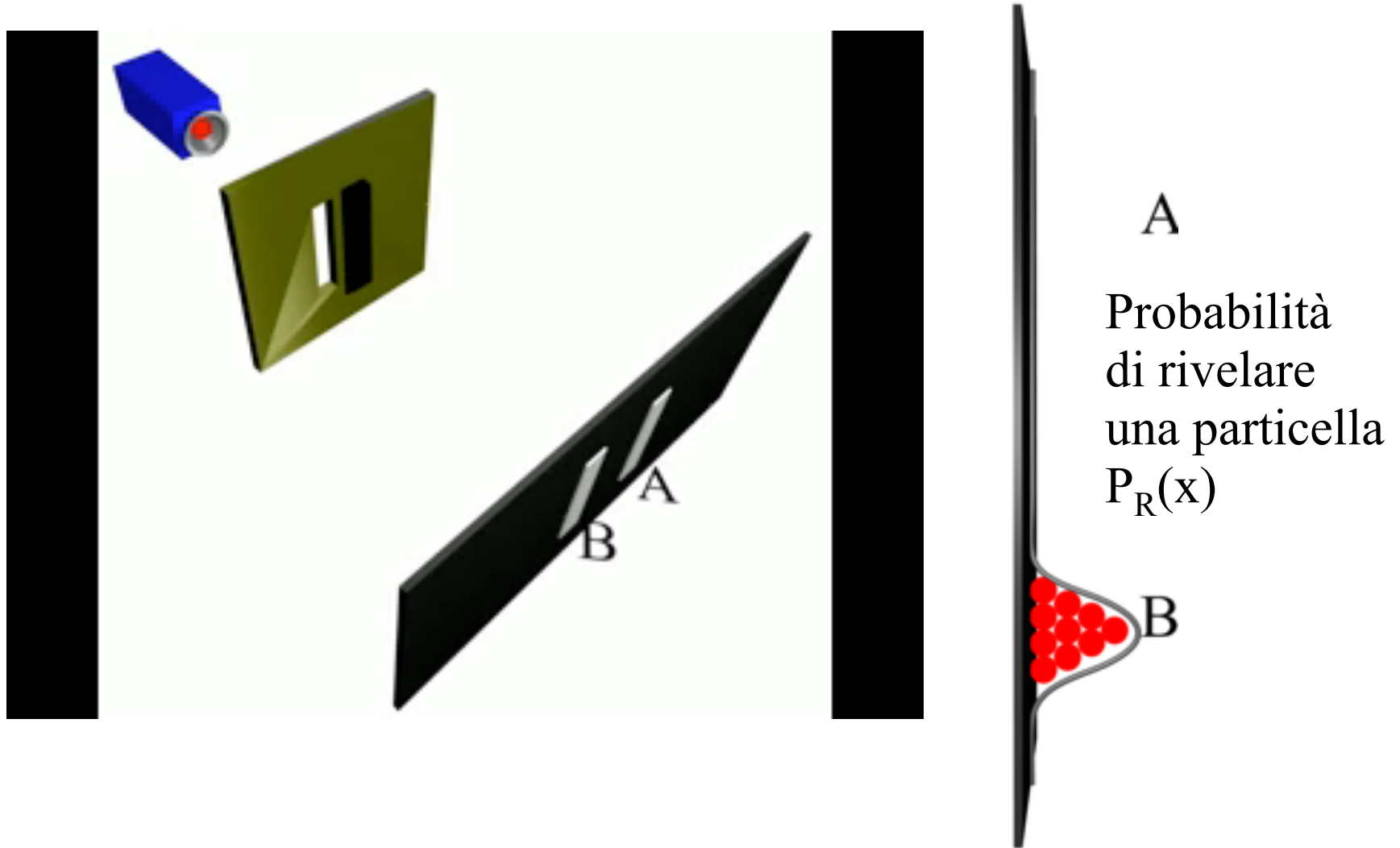
# Interferenza a singola particella



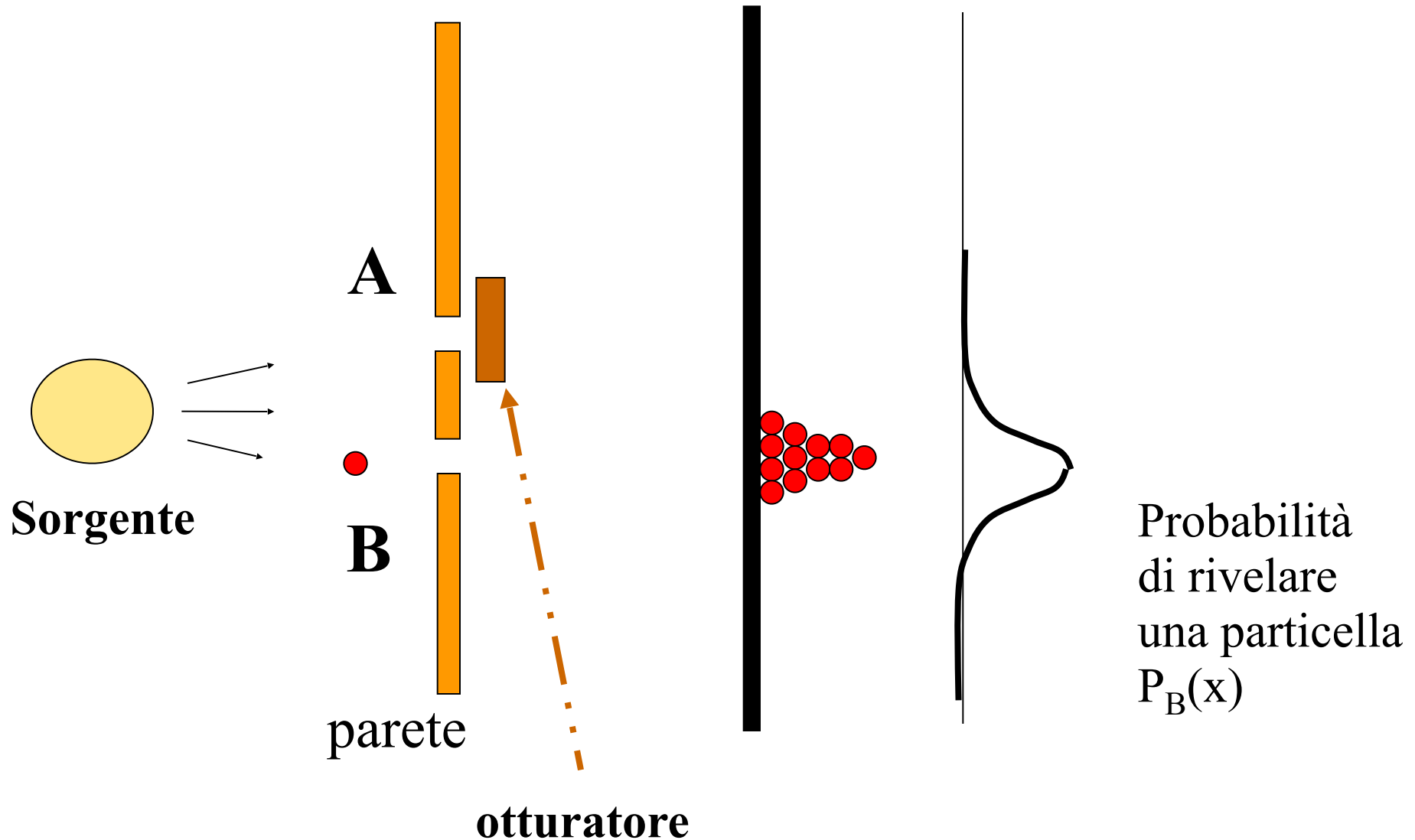
# Interferenza a singola particella



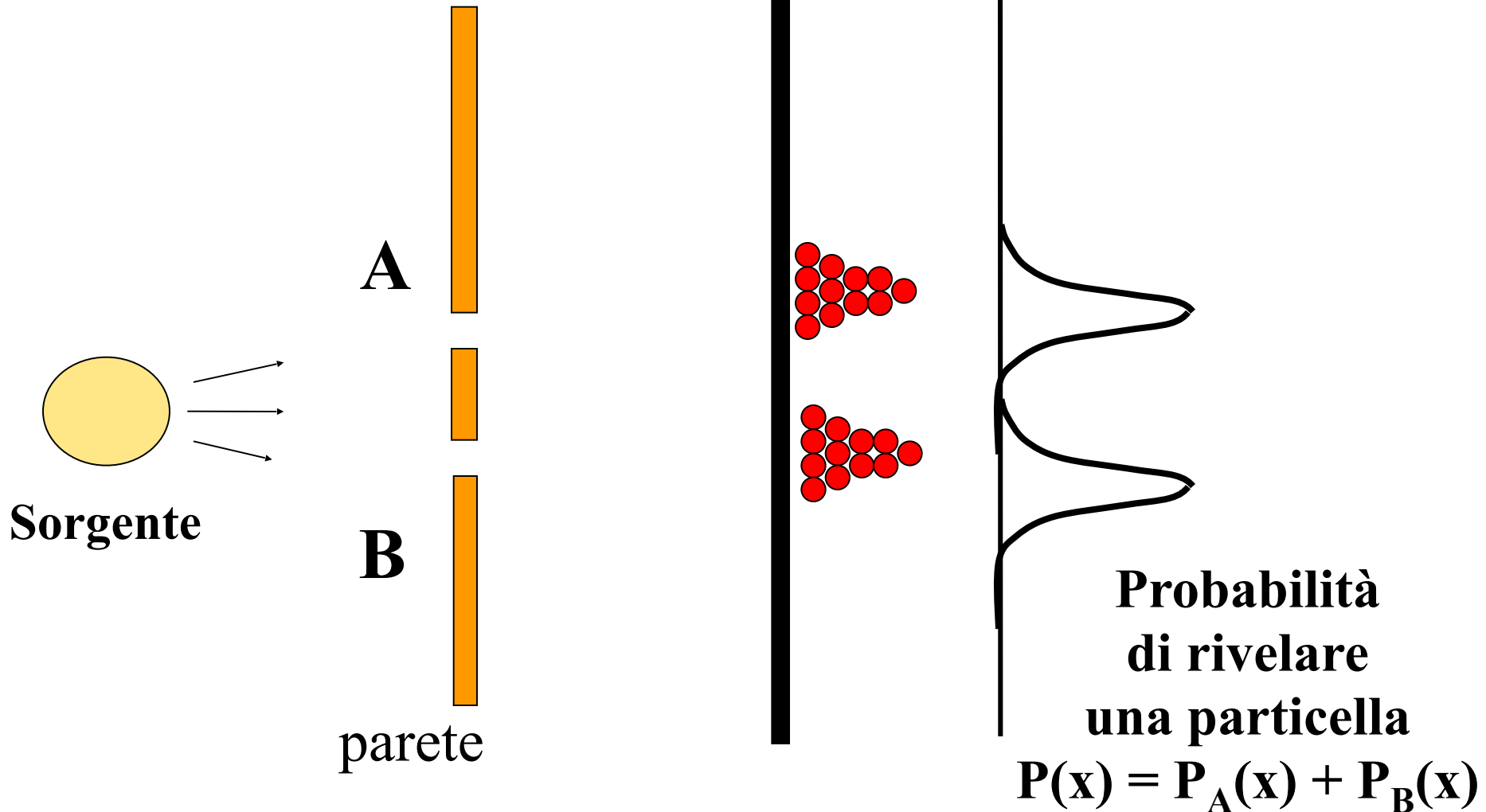
# Interferenza a singola particella



# Interferenza a singola particella

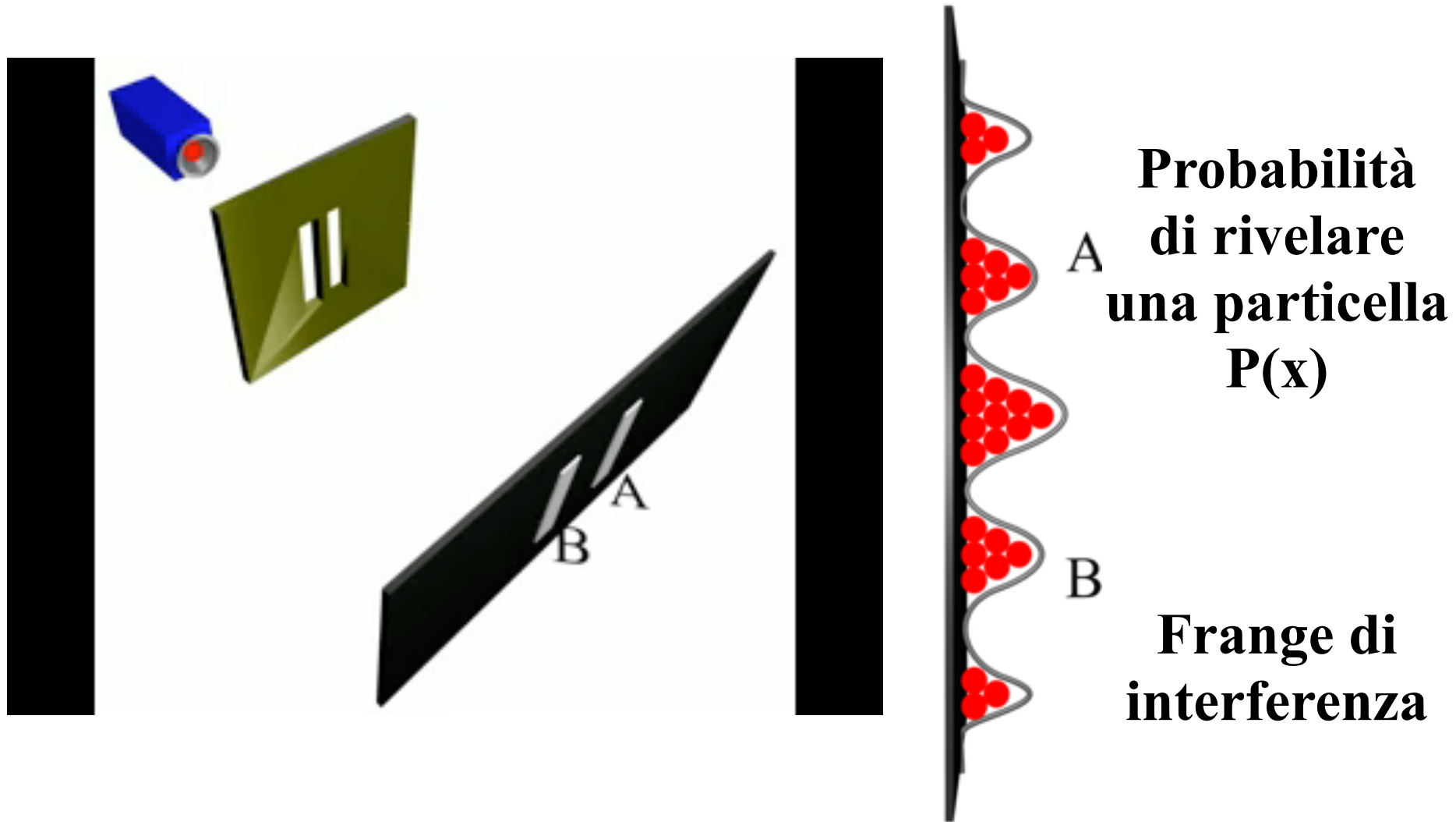


# Comportamento “classico”



# Interferenza quantistica

$$| \textit{fotone in A} \rangle + | \textit{fotone in B} \rangle$$



# Funzione d'onda



**Da quale fenditura passa il fotone ?**

**E' come se passasse da entrambe...**

# Interferenza quantistica

**Fisica classica:** una particella può viaggiare lungo il cammino A o lungo il cammino B

**Fisica quantistica:** “una particella può viaggiare lungo il cammino A e lungo il cammino B”

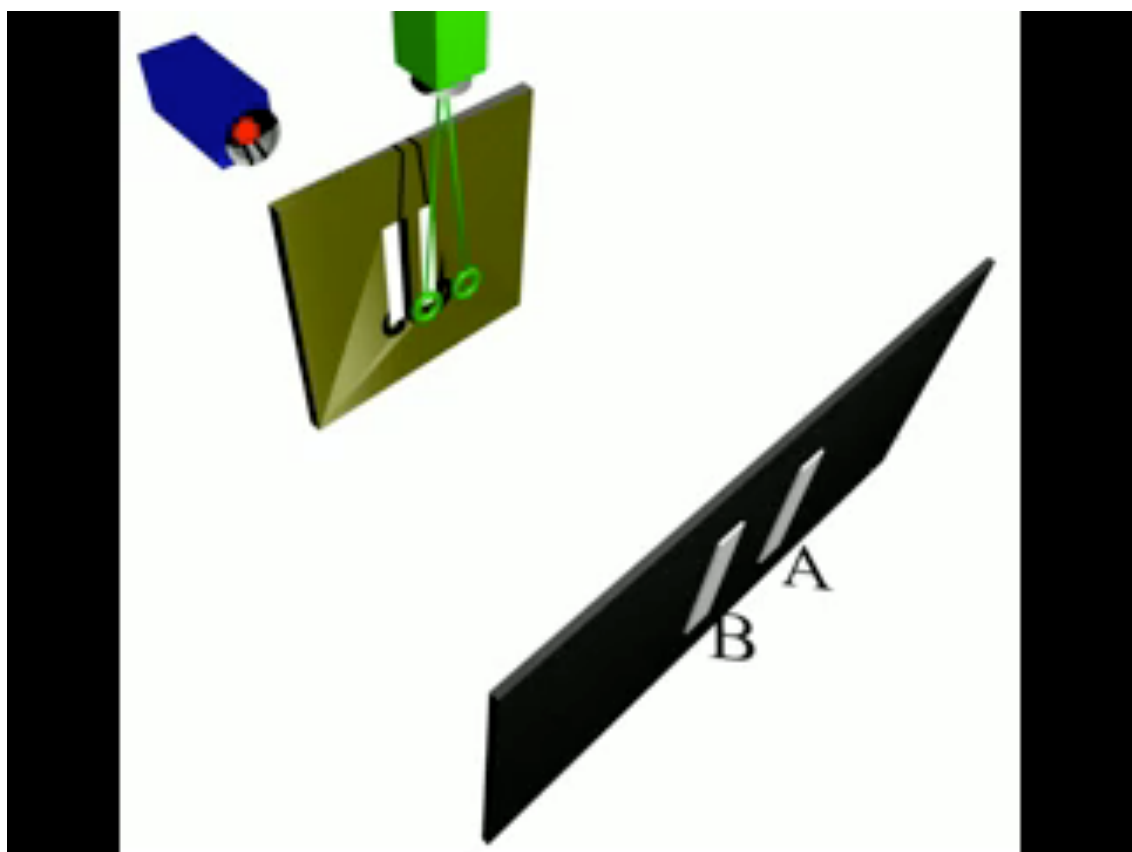
La particella si trova in uno stato di sovrapposizione delle due traiettorie.

**Come descriviamo lo *stato* del fotone?**

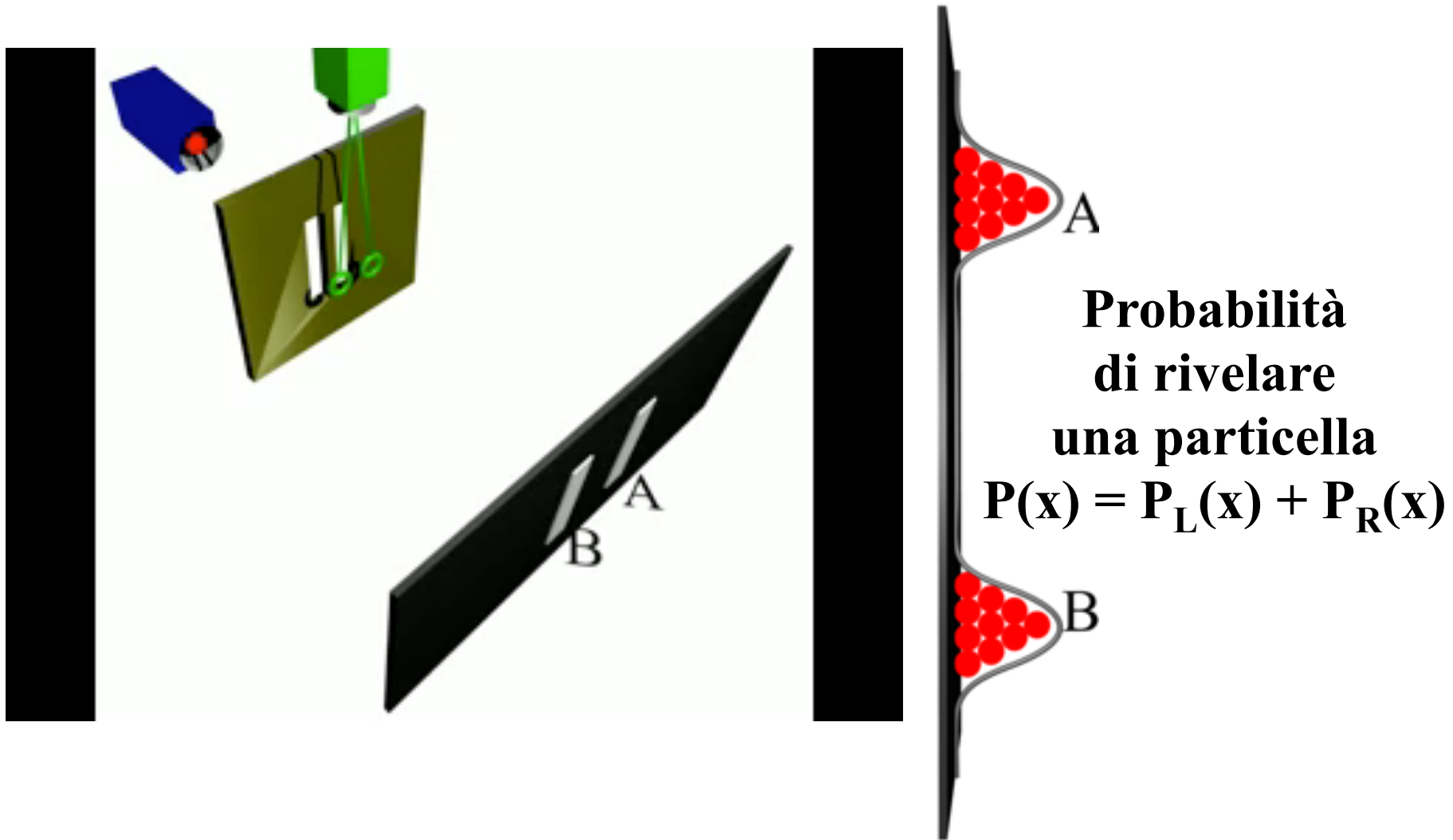
**Funzione d'onda**

$$| \textit{fotone in } A \rangle + | \textit{fotone in } B \rangle$$

**Sistemi quantistici vivono in  
spazi vettoriali con coefficienti complessi  
(spazi di Hilbert)**



# Comportamento “classico”



# “It from bit”

*J.A. Wheeler*

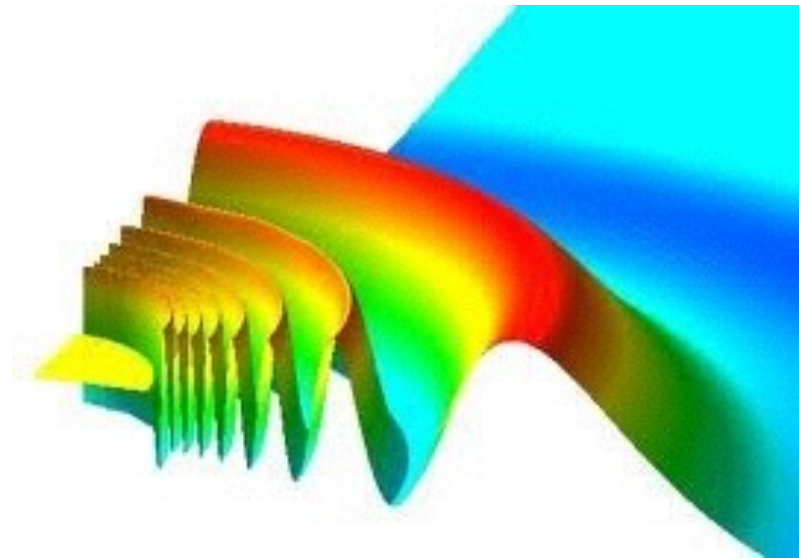
La realtà è creata anche dalle nostre domande,  
ovvero dall'informazione acquisita.

**L'osservazione perturba il fenomeno:  
[“Indeterminazione di Heisenberg”]**

# Che cos'è la funzione d'onda ?

La **funzione d'onda** rappresenta uno stato fisico del sistema quantistico.

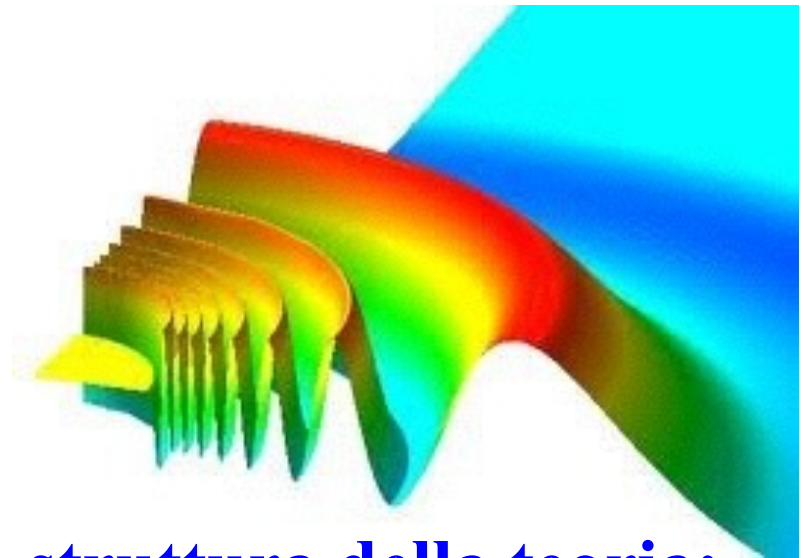
$\Psi$



# Che cos'è la funzione d'onda ?

La **funzione d'onda** rappresenta uno stato fisico del sistema quantistico.

$\Psi$



**La matematica domina la struttura della teoria:**  
**[ “funzione d’onda”  $|\Psi\rangle$  strumento per descrivere la realtà o sua essenza ?]**

$$| \textit{fotone in } A \rangle + | \textit{fotone in } B \rangle$$

La funzione d'onda:

## **EPISTEMOLOGIA**

«discorso sulla conoscenza»

*oppure*

## **ONTOLOGIA**

«discorso sull'essere»



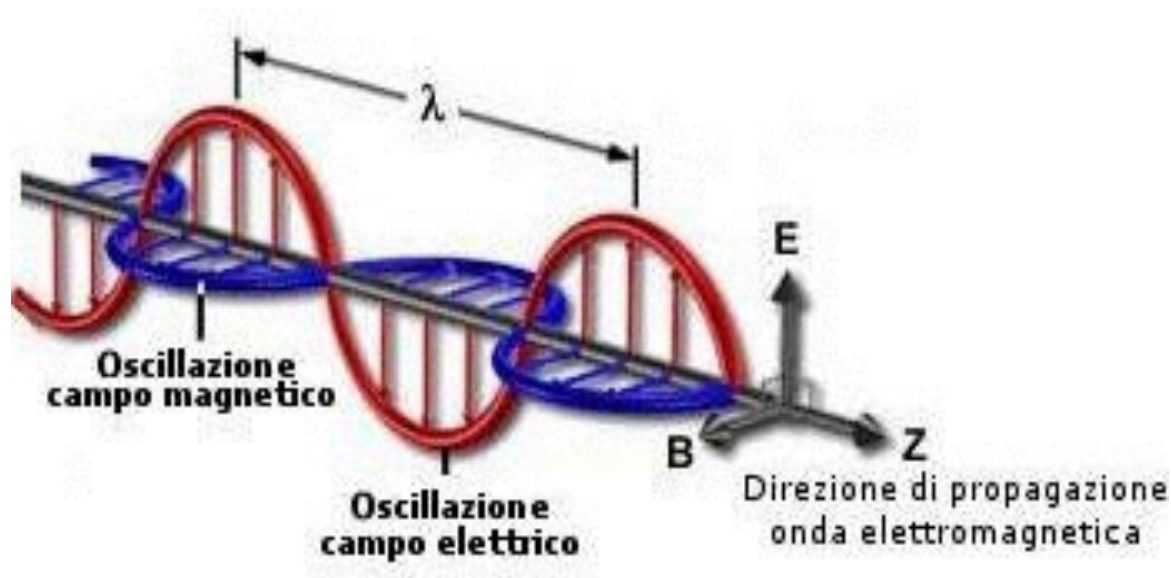
# *L'interpretazione di Copenhagen della Meccanica Quantistica:*

“Lo scopo della nostra descrizione della natura non è il cercare l’essenza reale dei fenomeni ma soltanto l’indagare con la massima profondità possibile le relazioni tra i molteplici aspetti della nostra esperienza.”

*Niels Bohr (1934)*

**FAPP interpretation (For All Practical Purposes)**  
*Per tutti i fini pratici*

# Polarizzazione di un singolo fotone



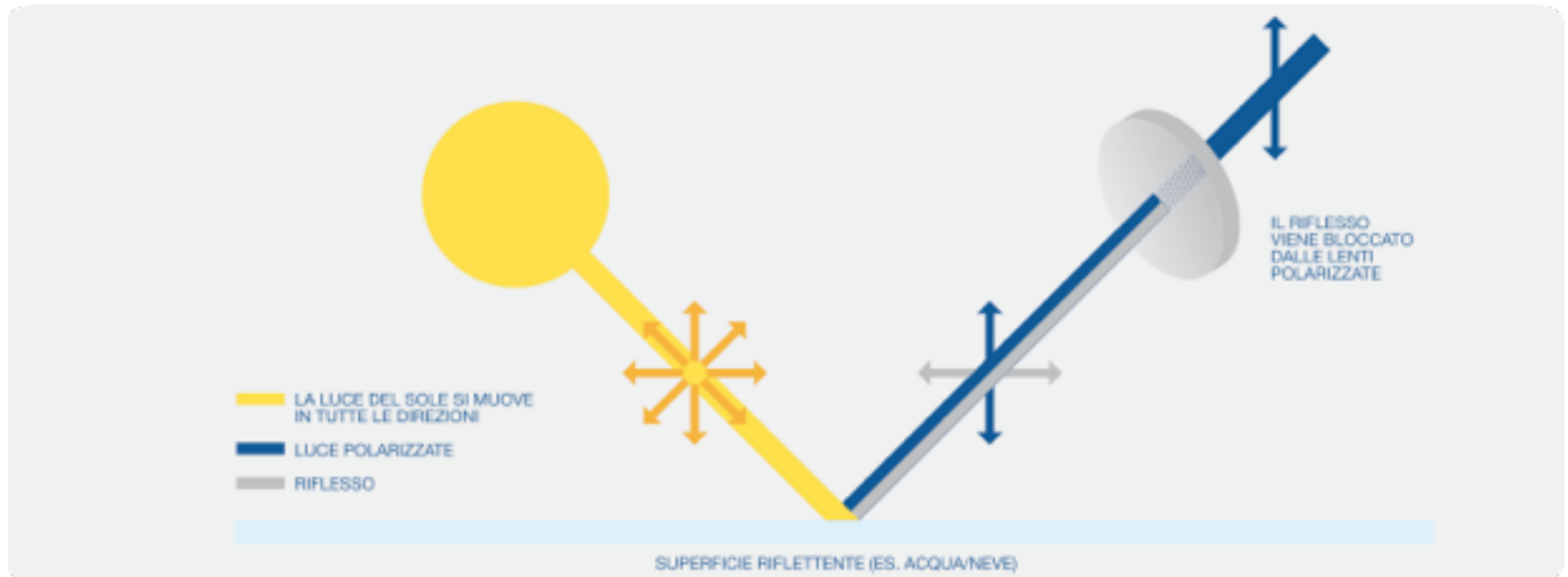
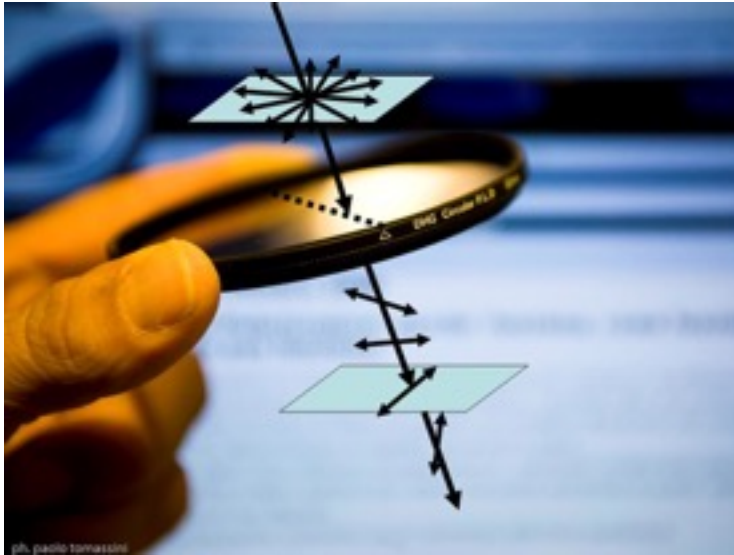
**Polarizzazione del singolo fotone**

$$\alpha|H\rangle + \beta|V\rangle$$

**H: orizzontale**

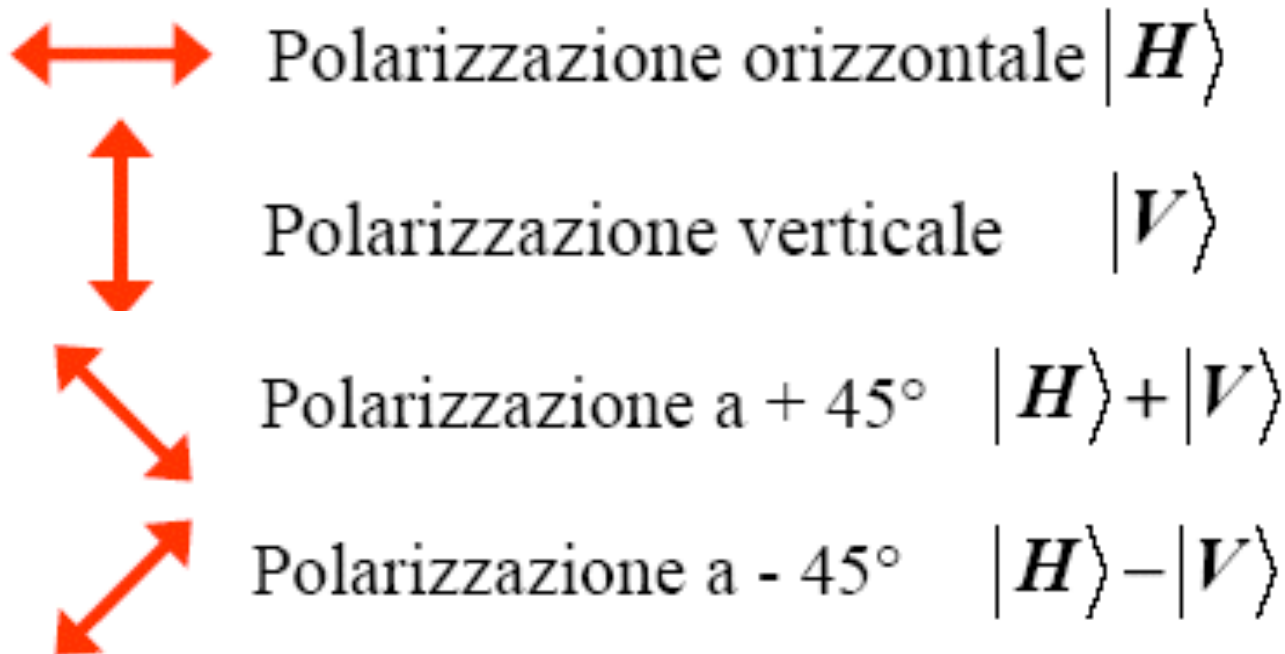
**V: verticale**

# Occhiali polarizzati

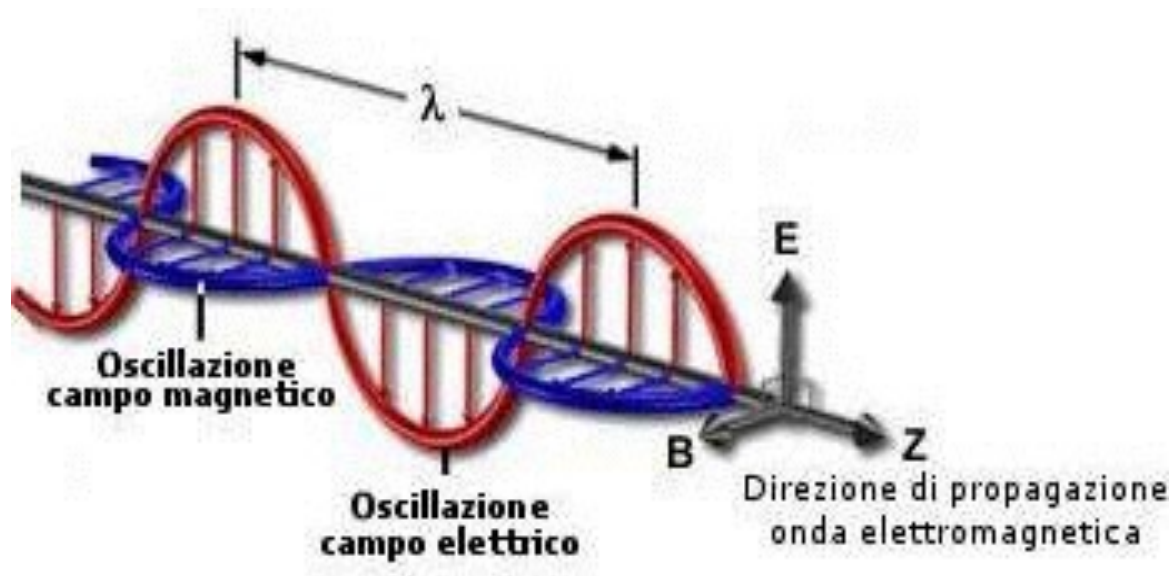


# Polarizzazione di un singolo fotone

Polarizzazione: direzione di oscillazione del campo elettromagnetico



# Polarizzazione di un singolo fotone



**Polarizzazione del singolo fotone**

$$\alpha|H\rangle + \beta|V\rangle \quad \longrightarrow \quad \alpha|0\rangle + \beta|1\rangle$$

**H: orizzontale**

**V: verticale**

**“A phenomenon is not a phenomenon until  
is a measured phenomenon...”**

***J. A. Wheeler***

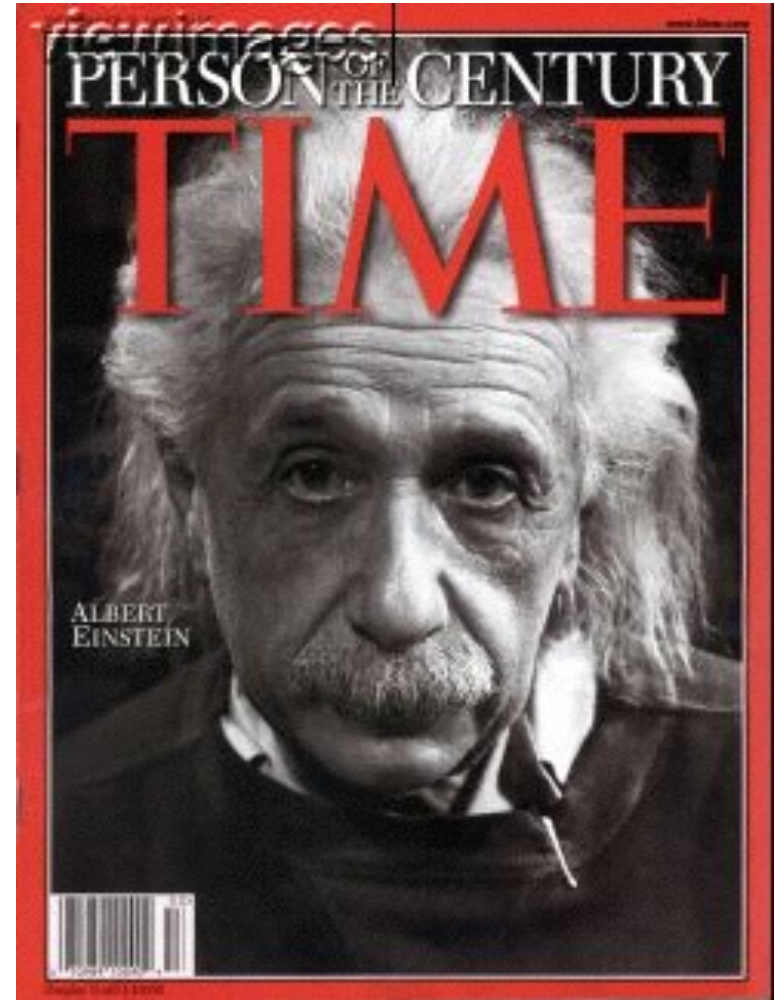
**“Esiste la luna in cielo se io non la  
guardo ?”**

***A. Einstein***

**Esistono le “proprietà oggettive”, gli  
“elements of physical reality” ?**

***A. Einstein***

# Einstein: « Dio non gioca a dadi »



# EINSTEIN ATTACKS QUANTUM THEORY

Scientist and Two Colleagues  
Find It Is Not 'Complete'  
Even Though 'Correct.'

SEE FULLER ONE POSSIBLE

Believe a Whole Description of  
'the Physical Reality' Can Be  
Provided Eventually.

Copyright 1935 by Science Service.  
PRINCETON, N. J., May 3.—Prof-  
essor Albert Einstein will attack  
science's important theory of quan-  
tum mechanics, a theory of which  
he was a sort of grandfather. He  
concludes that while it is "correct"  
it is not "complete."

With two colleagues at the Insti-  
tute for Advanced Study here, the  
noted scientist is about to report to  
the American Physical Society what  
is wrong with the theory of quan-  
tum mechanics, it has been learned  
exclusively by Science Service.

The quantum theory, with which  
science predicts with some success  
inter-atomic happenings, does not  
meet the requirements for a satis-  
factory physical theory, Professor  
Einstein will report in a joint paper  
with Dr. Boris Podolsky and Dr.  
N. Rosen.

In the quantum theory as now  
used, the latest Einstein paper will

point out that where two physical  
quantities such as the position of a  
particle and its velocity interact, a  
knowledge of one quantity pre-  
cludes knowledge about the other.  
This is the famous principle of un-  
certainty put forward by Professor  
Werner Heisenberg and incorpor-  
ated in the quantum theory. This  
very fact, Professor Einstein feels,  
makes the quantum theory fall in  
the requirements necessary for a  
satisfactory physical theory.

## Two Requirements Listed.

These two requirements are:  
1. The theory should make pos-  
sible a calculation of the facts of  
nature and predict results which  
can be accurately checked by ex-  
periment; the theory should be, in  
other words, correct.

2. Moreover, a satisfactory theory  
should, as a good image of the ob-  
jective world, contain a counter-  
part for things found in the objec-  
tive world; that is, it must be a  
complete theory.

Quantum theory, Professor Ein-  
stein and his colleagues will report,  
fulfills the correctness requirement  
but falls in the completeness re-  
quirement.

While proving that present quan-  
tum theory does not give a com-  
plete description of physical reality,  
Professor Einstein believes some  
later, still undeveloped, theory will  
make this possible. His conclusion  
is:

"While we have thus shown that  
the wave function [of quantum  
theory] 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."

The development of quantum me-  
chanics has proved very useful in  
exploring the atom. Six Nobel  
Prizes in physics, including one  
to Einstein, have been awarded  
for various phases of the researches  
leading up to quantum mechanics.

The names of Planck, Bohr, de  
Broglie, Heisenberg, Dirac and  
Schrodinger, as well as Einstein,  
are linked with quantum mechanics.

The exact title of the Einstein-  
Podolsky-Rosen paper is: "Can  
Quantum-Mechanical Description of  
Physical Reality Be Considered  
Complete?"

## Explanation by Podolsky.

In explaining the latest view of  
the physical world as revealed in  
their researches Dr. Podolsky, one  
of the authors, said:

"Physicists believe that there  
exist real material things independ-  
ent of our minds and our theories.  
We construct theories and invent  
words (such as electron, positron,  
&c.) in an attempt to explain to  
ourselves what we know about our  
external world and to help us to  
obtain further knowledge of it. Be-  
fore a theory can be considered to  
be satisfactory it must pass two  
very severe tests. First, the theory  
must enable us to calculate facts of  
nature, and these calculations must  
agree very accurately with observa-  
tions and experiments. Second, we  
expect a satisfactory theory, as a  
good image of objective reality, to  
contain a counterpart for every ele-  
ment of the physical world. A  
theory satisfying the first require-  
ment may be called a correct  
theory while, if it satisfies the sec-  
ond requirement, it may be called  
a complete theory.

"Hundreds of thousands of ex-  
periments and measurements have  
shown that, at least in cases when  
matter moves much slower than  
light, the theory of Planck, Ein-  
stein, Bohr Heisenberg and  
Schrodinger known as quantum  
mechanics is a correct theory.  
Einstein, Podolsky and Rosen now  
discuss the question of the com-  
pleteness of quantum mechanics.  
They arrive at the conclusion that  
quantum mechanics, in its present  
form, is not complete.

"In quantum mechanics the con-  
dition of any physical system, such

as an electron, an atom, &c., is  
supposed to be completely de-  
scribed by a formula known as a  
'wave function.' Suppose that we  
know the wave function for each  
of two physical systems, and that  
these two systems come together,  
interact, and again separate (as  
when two particles collide and  
move apart). Quantum mechanics,  
although giving us considerable in-  
formation about such a process,  
does not enable us to calculate the  
wave function of each physical sys-  
tem after the separation. This fact  
is made use of in showing that the  
wave function does not give a  
complete description of physical  
reality. Since, however, descrip-  
tion of physical systems by wave  
functions is an essential step of  
quantum mechanics, this means  
that quantum mechanics is not a  
complete theory."

## Raises Point of Doubt.

Special to THE NEW YORK TIMES.

PRINCETON, N. J., May 3.—  
Asked to comment on the new ideas  
of Professor Einstein and his col-  
laborators, Professor Edward U.  
Condon, mathematical physicist of  
Princeton University, said tonight:

"Of course, a great deal of the  
argument hinges on just what mean-  
ing is to be attached to the word  
'reality' in connection with physics.  
They have certainly discussed an  
interesting point in connection with  
the theory. Dr. Einstein has never  
been satisfied with the statistical  
causality which in the new theories  
replaces the strict causality of the  
old physics.

"It is reported that when he first  
learned of the work of Schrodinger  
and Dirac, he said, 'Der lieber  
Gott wuerfelt nicht, (the good Lord  
does not throw dice). For the last  
five years he has subjected the  
quantum mechanical theories to  
very searching criticism from this  
standpoint. But I am afraid that  
thus far the statistical theories have  
withstood criticism."

# **Paradosso di Einstein-Podolsky-Rosen**

**Per dimostrare che la Meccanica Quantistica**

**NON è la teoria definitiva**

**introducono il concetto di entanglement**

# Paradosso di Einstein-Podolsky-Rosen

Per dimostrare che la Meccanica Quantistica

**NON** è la teoria definitiva

introducono il concetto di entanglement

Consideriamo due particelle (fotoni A e B)

$$|0\rangle_A |1\rangle_B$$

# Paradosso di Einstein-Podolsky-Rosen

Per dimostrare che la Meccanica Quantistica

**NON** è la teoria definitiva

introducono il concetto di entanglement

Consideriamo due particelle (fotoni A e B)

$$|1\rangle_A |0\rangle_B$$

# Paradosso di Einstein-Podolsky-Rosen

Per dimostrare che la Meccanica Quantistica

**NON** è la teoria definitiva

introducono il concetto di entanglement

Consideriamo due particelle (fotoni A e B)

$$|0\rangle_A |1\rangle_B$$

$$+$$

$$|1\rangle_A |0\rangle_B$$

# Paradosso di Einstein-Podolsky-Rosen

Per dimostrare che la Meccanica Quantistica

**NON** è la teoria definitiva

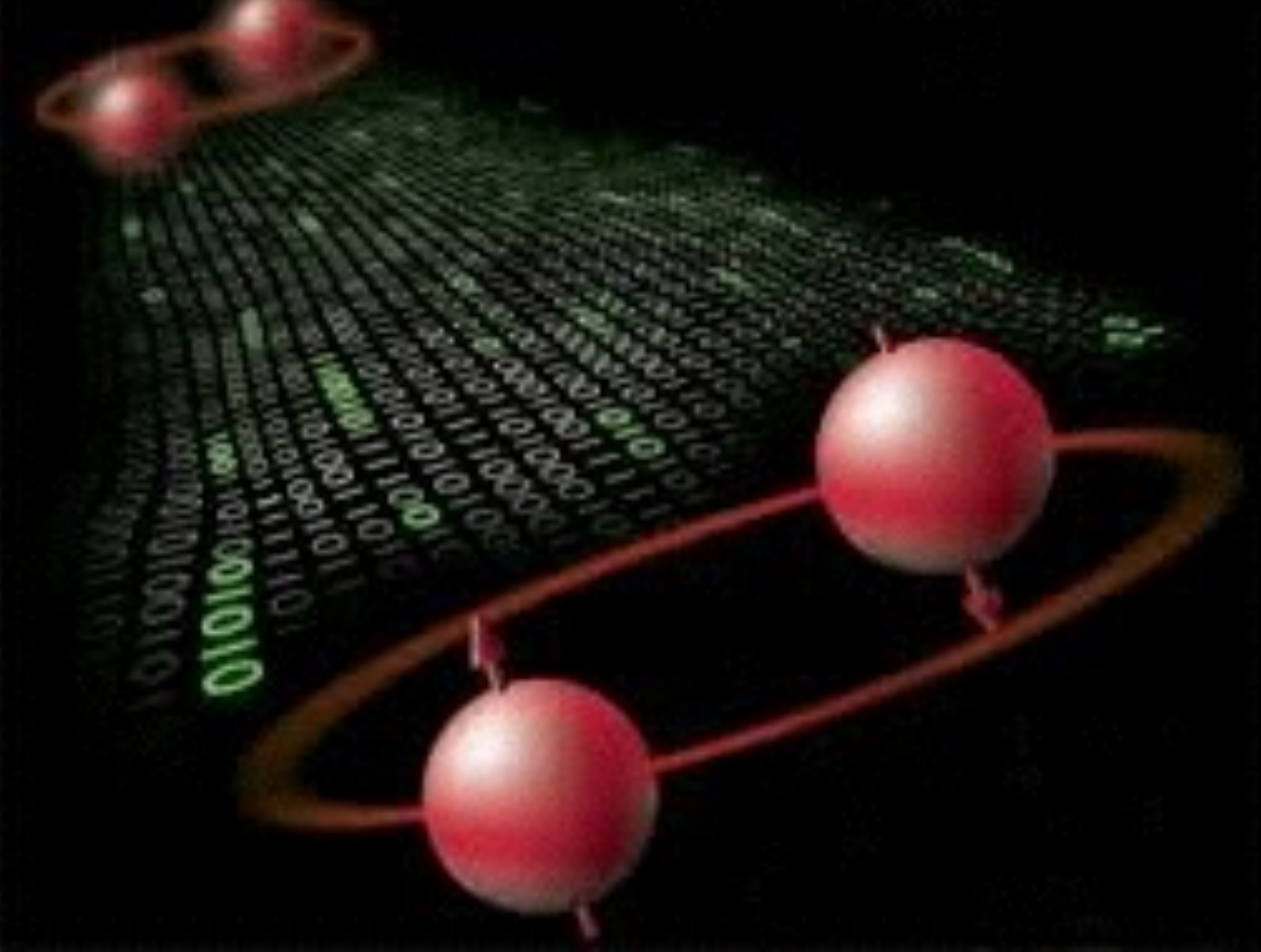
introducono il concetto di entanglement

Consideriamo due particelle (fotoni A e B)

$$|\Psi\rangle_{AB} = \frac{|0\rangle_A |1\rangle_B - |1\rangle_A |0\rangle_B}{\sqrt{2}}$$

**Entanglement:**

*due particelle aggrovigliate*



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.

## EINSTEIN ATTACKS QUANTUM THEORY

Scientist and Two Colleagues  
Find It Is Not 'Complete'  
Even Though 'Correct'

SEE FULLER ONE POSSIBLE

Believe a Whole Description  
'the Physical Reality' Can Be  
Provided Eventually.

other words, correct.

2. Moreover, a satisfactory theory should, as a good image of the objective world, contain a counterpart for things found in the physical

external world and to help us to obtain further knowledge of it. Before a theory can be considered to be satisfactory it must pass two very severe tests. First, the theory

that quantum mechanics is not a complete theory."

Raises Point of Doubt.

*« While we have 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. »*

N. Rosen.

In the quantum theory as now used, the latest Einstein paper will

prizes in physics, including one to Einstein, have been awarded for various phases of the researches leading up to quantum mechanics.

quantum mechanics. In its present form, is not complete.

"In quantum mechanics the condition of any physical system, such

standpoint. But I am afraid that thus far the statistical theories have withstood criticism."

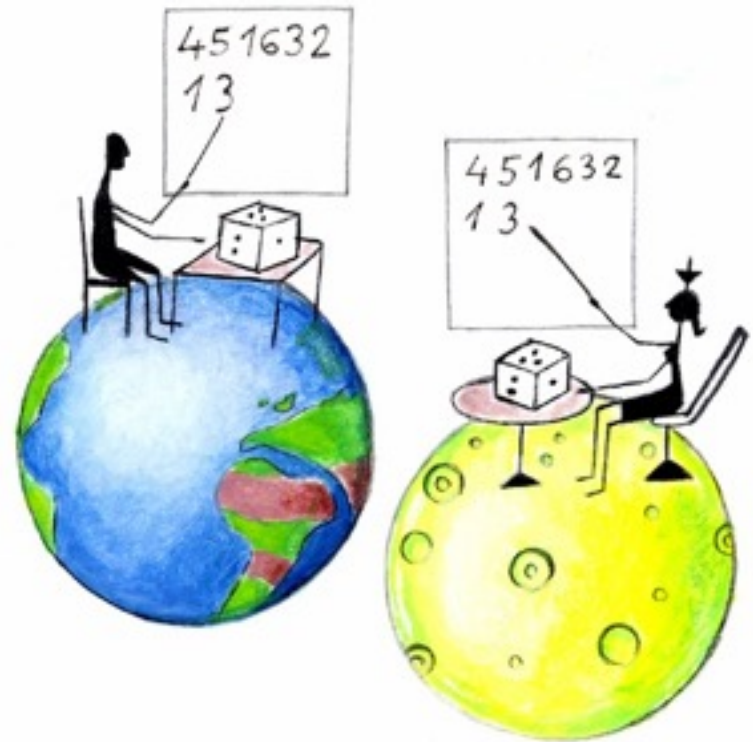
$$|\Psi\rangle_{AB} = \frac{|0\rangle_A |1\rangle_B - |1\rangle_A |0\rangle_B}{\sqrt{2}}$$

« I would not call **entanglement** one but rather the **characteristic trait of quantum mechanics**,  
the one that enforces its entire departure from classical lines of thought. »

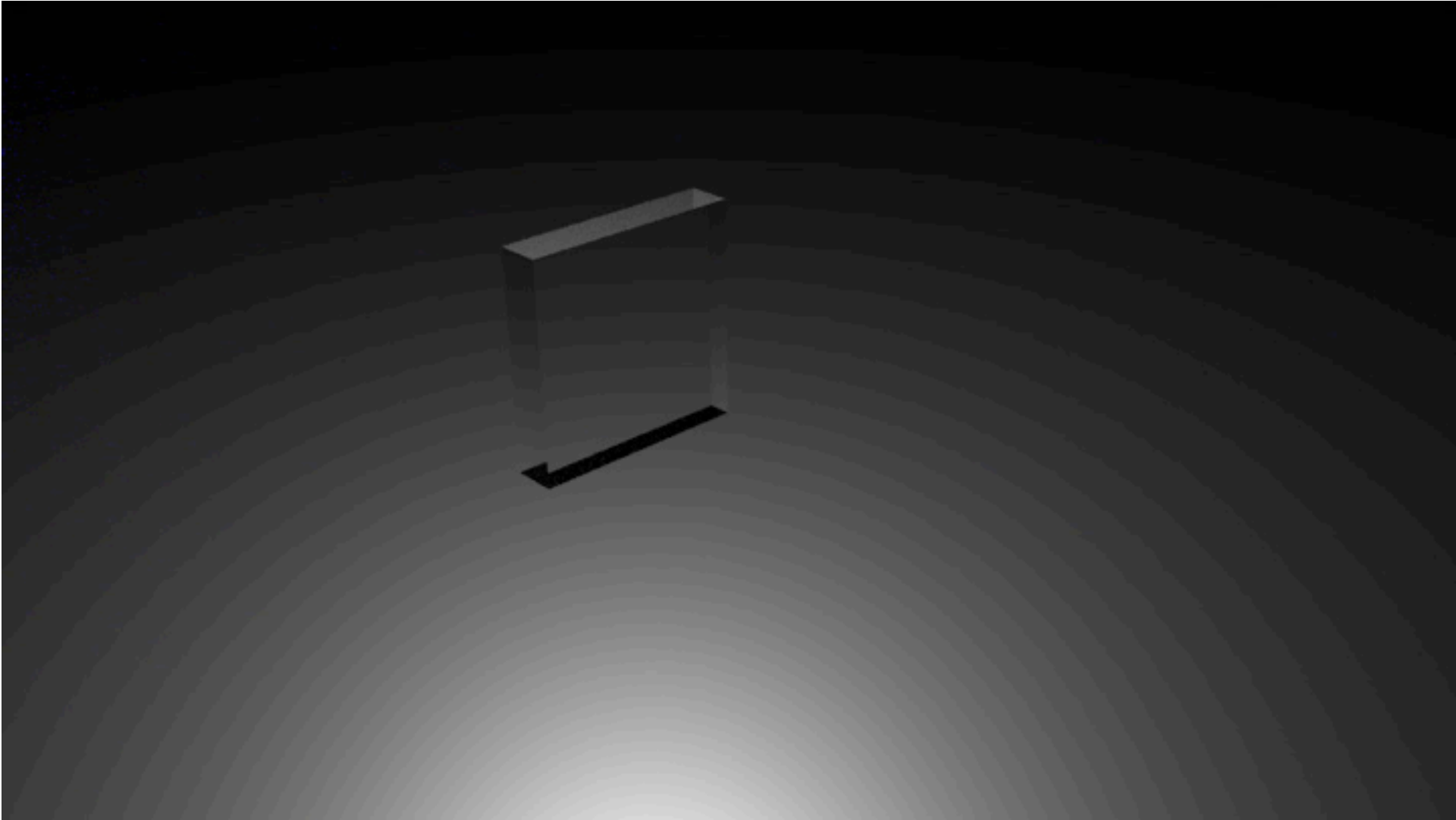
*E. Schroedinger*

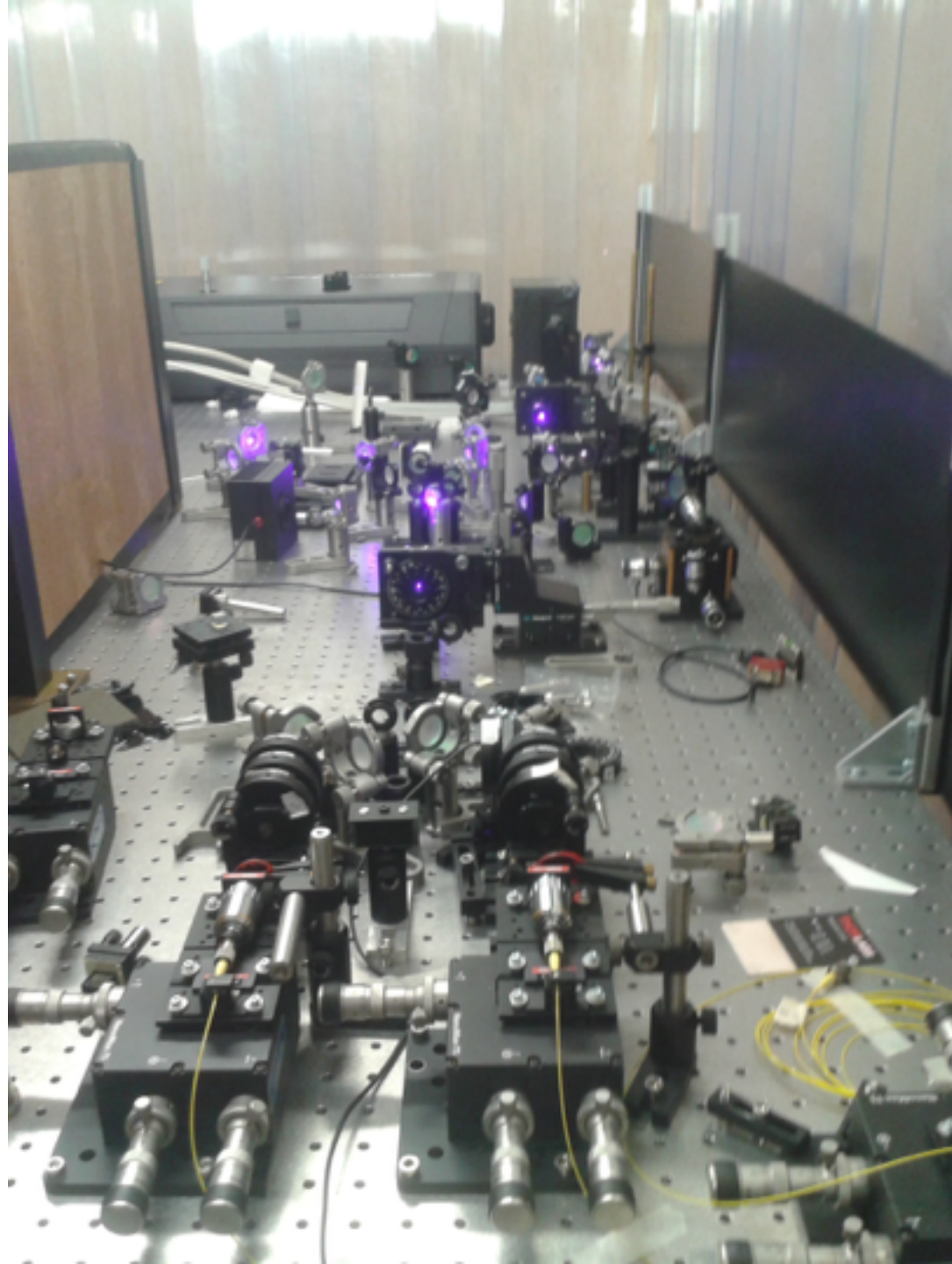
# Non-località quantistica

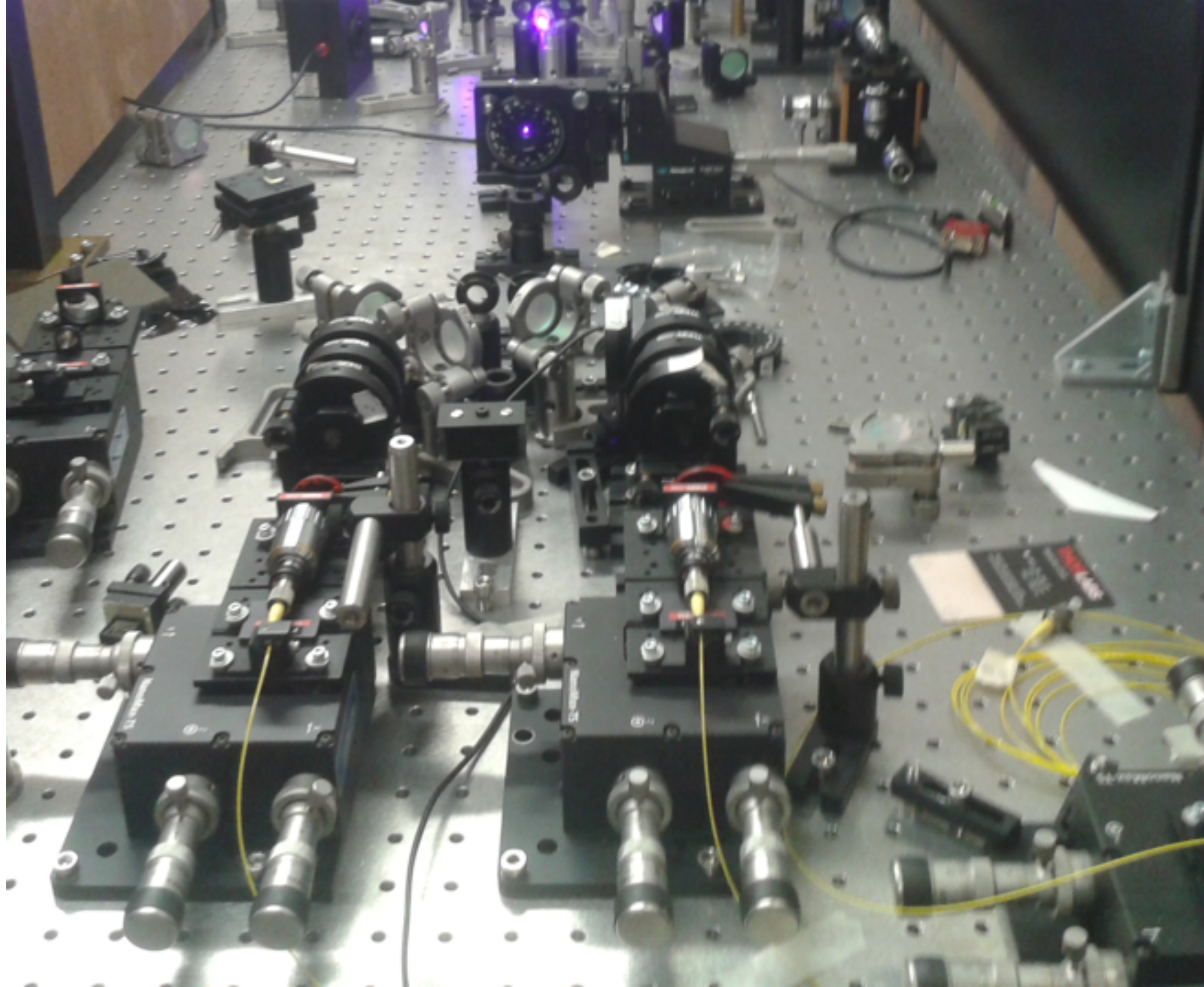
...non importa quanto spazio intercorra tra due particelle correlate, queste comunicheranno fra di loro come se non ci fosse alcuno spazio...



# Generazione di stati entangled





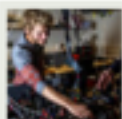


# Violation of local realism with freedom of choice

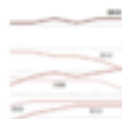
Thomas Scheidl<sup>a</sup>, Rupert Ursin<sup>a</sup>, Johannes Kofler<sup>a,b,1</sup>, Sven Ramelow<sup>a,b</sup>, Xiao-Song Ma<sup>a,b</sup>, Thomas Herbst<sup>b</sup>, Lothar Ratschbacher<sup>a,2</sup>, Alessandro Fedrizzi<sup>a,3</sup>, Nathan K. Langford<sup>a,4</sup>, Thomas Jennewein<sup>a,5</sup>, and Anton Zeilinger<sup>a,b,1</sup>

<sup>a</sup>Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria; and <sup>b</sup>Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria





Sorry, Einstein. Quantum Study Suggests 'Spooky Action' Is Real.



2015 Likely to Be Hottest Year Ever Recorded



Museum Specimens Find New Life Online



New Species of Galápagos Tortoise Is Identified

## SCIENCE

710 COMMENTS

# Sorry, Einstein. Quantum Study Suggests 'Spooky Action' Is Real.

By JOHN MARKOFF OCT. 21, 2015



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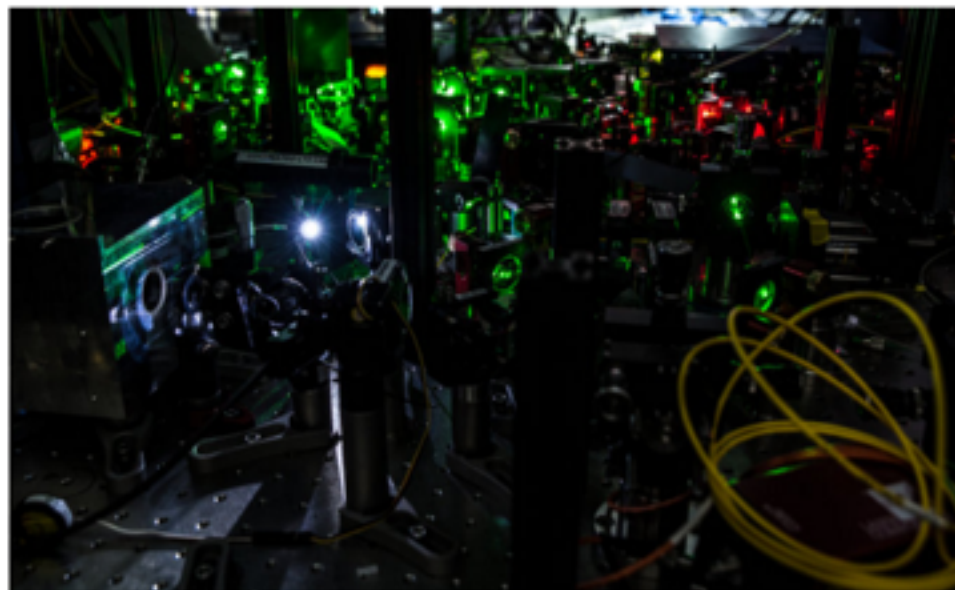


More

HE NAMED ME  
MALALA

In a landmark study, scientists at Delft University of Technology in the [Netherlands](#) reported that they had conducted an experiment that they say proved one of the most fundamental claims of quantum theory — that objects separated by great distance can instantaneously affect each other's behavior.

The finding is another blow to one of the bedrock principles of standard physics known as "locality," which states that an object is directly influenced only by its immediate surroundings. The Delft [study](#), published Wednesday in the journal *Nature*, lends further credence to an idea that Einstein famously rejected. He said

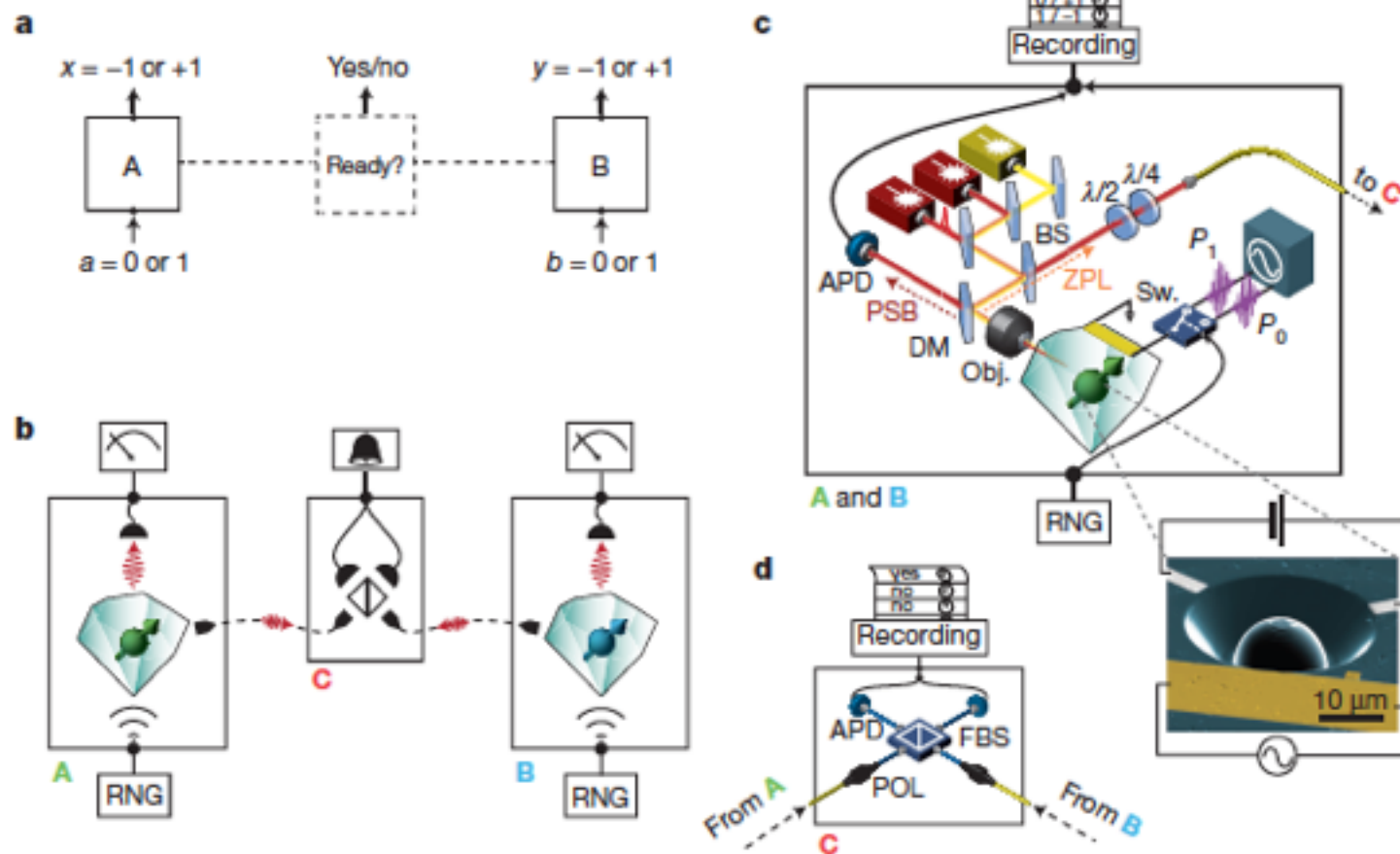


Part of the laboratory setup for an experiment at Delft University of Technology, in which two diamonds were set 1.3 kilometers apart, entangled and then shared information.

Frank Auperle/Delft University of Technology

## Loophole-free Bell inequality violation using electron spins separated by 1.3 kilometres

B. Hensen<sup>1,2</sup>, H. Bernien<sup>1,2†</sup>, A. E. Dréau<sup>1,2</sup>, A. Reiserer<sup>1,2</sup>, N. Kalb<sup>1,2</sup>, M. S. Blok<sup>1,2</sup>, J. Ruitenbergh<sup>1,2</sup>, R. F. L. Vermeulen<sup>1,2</sup>, R. N. Schouten<sup>1,2</sup>, C. Abellán<sup>3</sup>, W. Amaya<sup>3</sup>, V. Pruneri<sup>3,4</sup>, M. W. Mitchell<sup>3,4</sup>, M. Markham<sup>5</sup>, D. J. Twitchen<sup>5</sup>, D. Elkouss<sup>1</sup>, S. Wehner<sup>1</sup>, T. H. Taminiau<sup>1,2</sup> & R. Hanson<sup>1,2</sup>



A dark, atmospheric image of a forest path. Sunlight filters through the dense canopy of tall trees, creating a dappled pattern of light and shadow on the ground. The path leads into the distance, flanked by thick foliage. The overall mood is mysterious and serene.

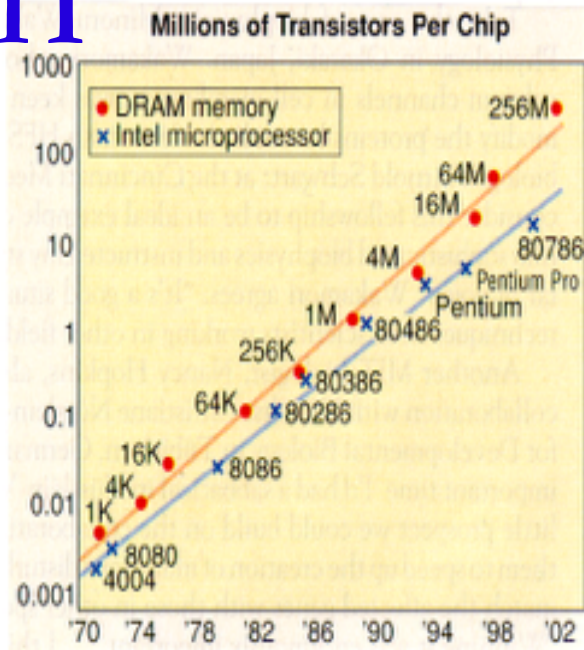
**“L'informazione è fisica”**

**R. Landauer**

**La manipolazione dell'informazione  
è governata dalle leggi della fisica.**

# L'evoluzione della Information Technology

**BIT**



**1879**

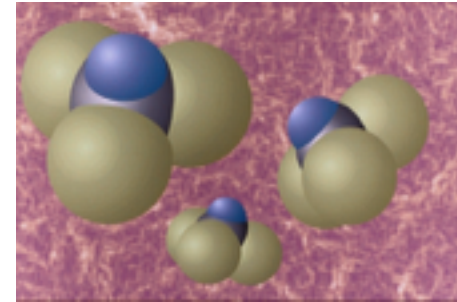


**1986**



**1 micron**

**2020**



**1 nanometro**

**BIT:**

**Variabile dicotomica**

**0**

**o**

**1**

# La Macchina di Turing (1936)

*Obiettivo: decifrare i codici Enigm...*

**ENIGMA:**

1940 II world war



La macchina di Turing:  
*modello astratto per descrivere una  
macchina capace di eseguire un algoritmo*

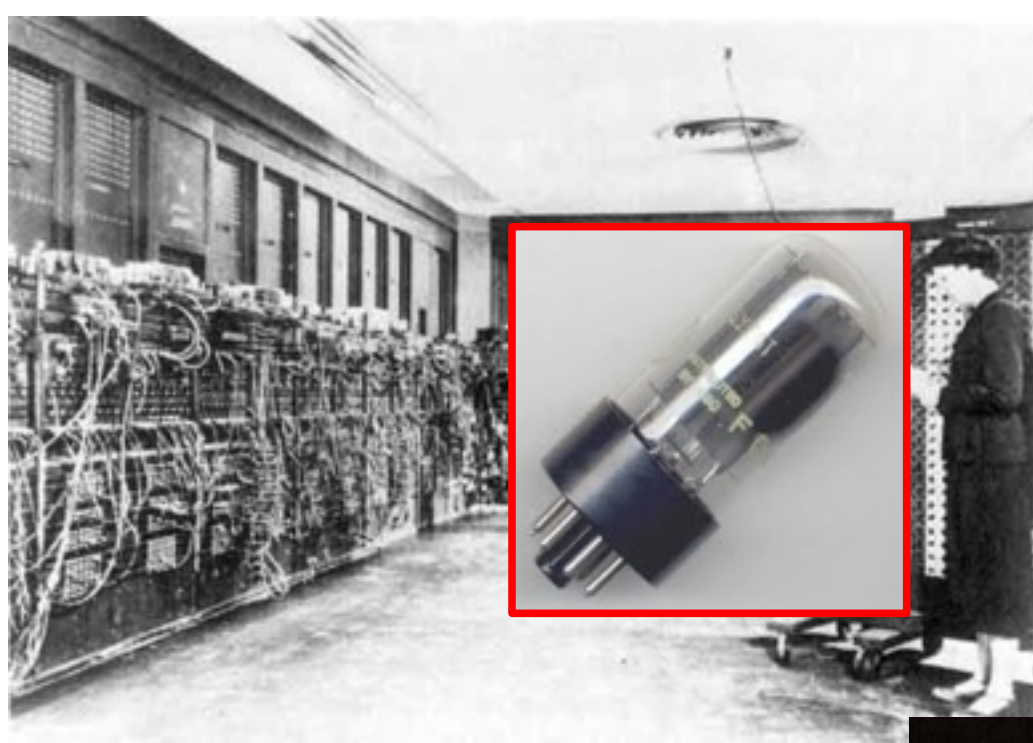


Movie: The Imitation Game

# ENIAC (1946)

## Electronic Numerical Integrator And Computer

18.000 thermionic valves,  
30 tons,  
180 mq

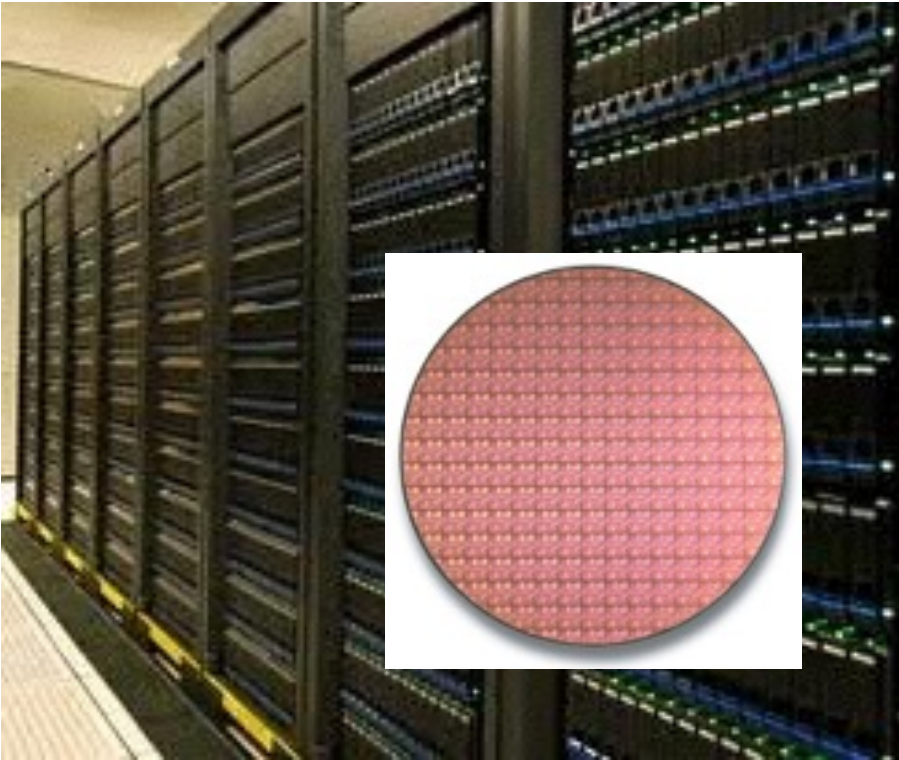


# Apple I (1976)

.. 4 Kb di Ram...!



**OGGI..**



**Tianhe-1A  
(2010)  
Supercomputer**

Operations per second

1 PetaFlops

**I-Phone 4s (2012)**

RAM 512 Mb

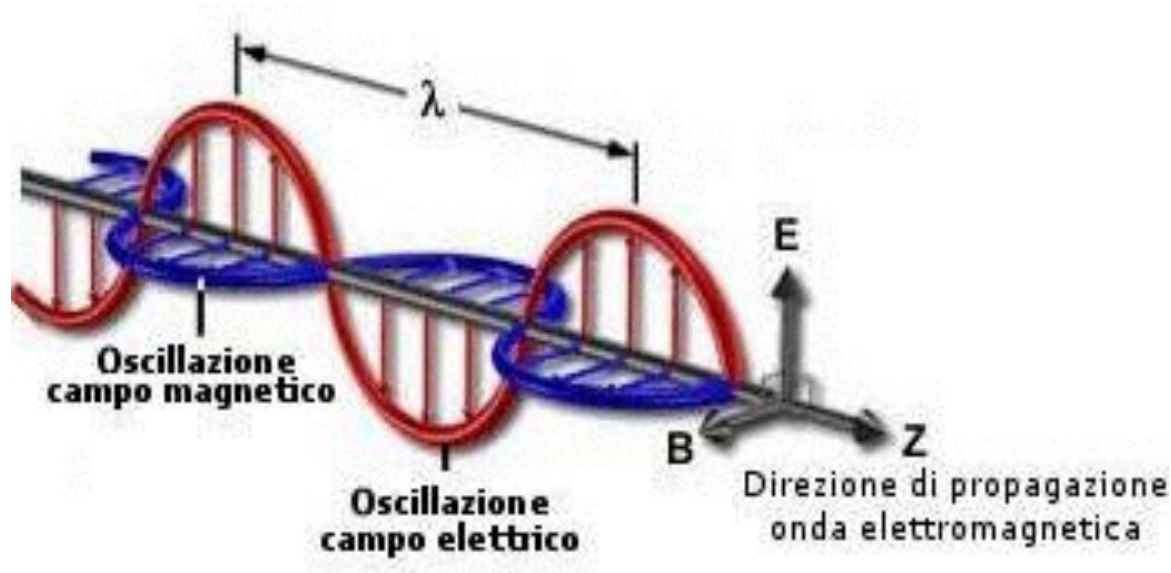


# QUBIT (Quantum Bit)

$$\alpha|0\rangle + \beta|1\rangle$$

**QUANTUM INFORMATION**

# Polarizzazione di un singolo fotone



**Qubit**



**Polarizzazione del singolo fotone**

$$\alpha|0\rangle + \beta|1\rangle$$

$$\alpha|H\rangle + \beta|V\rangle$$

**H: orizzontale**

**V: verticale**

# Crittografia Classica

**Cifrario di Cesare:**

I sec a.C

**Manoscritto di Voynich:**

XV sec d.C

**ENIGMA:**

1940 II guerra mondiale

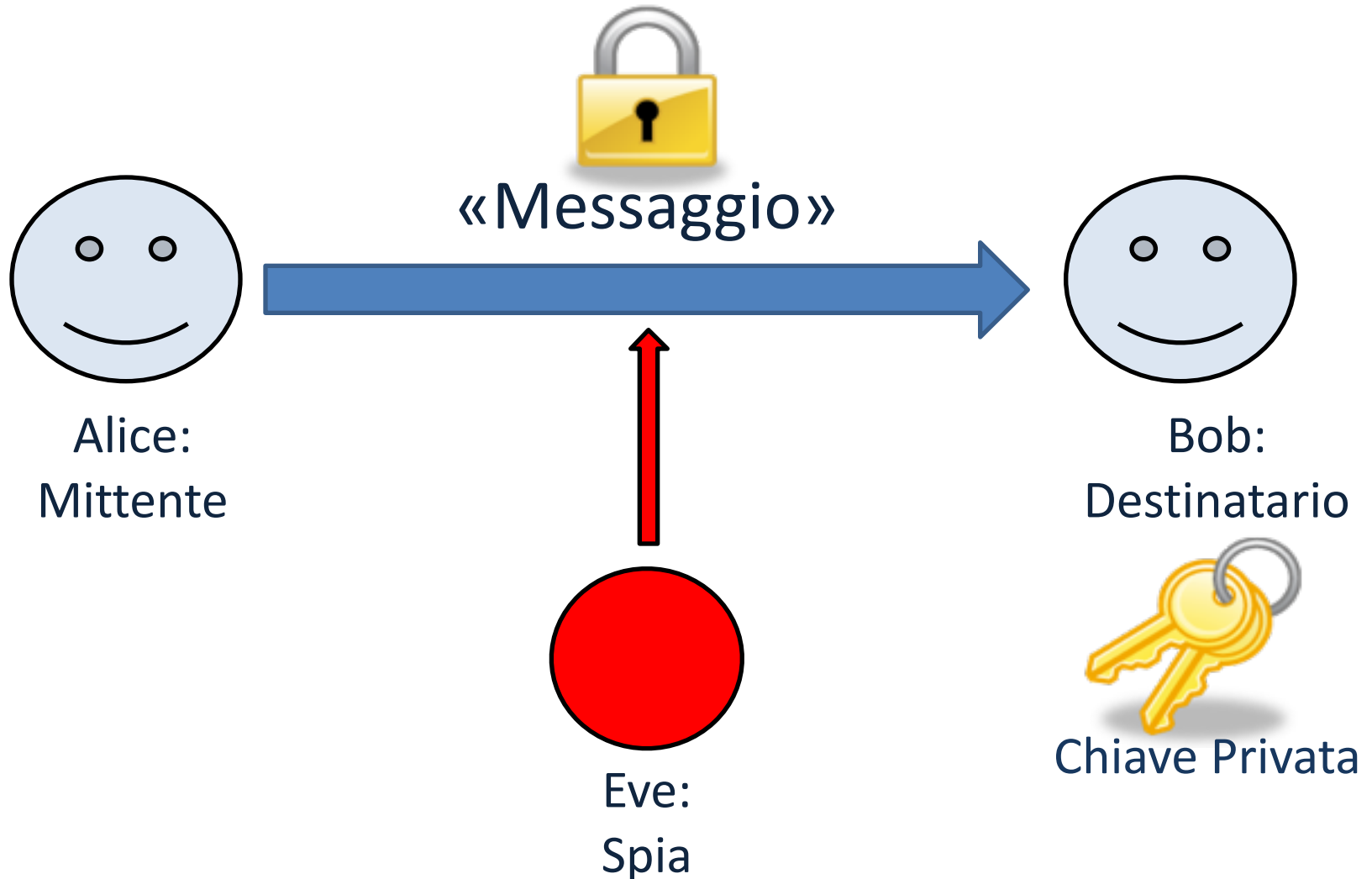
**Internet:**

1990 - oggi

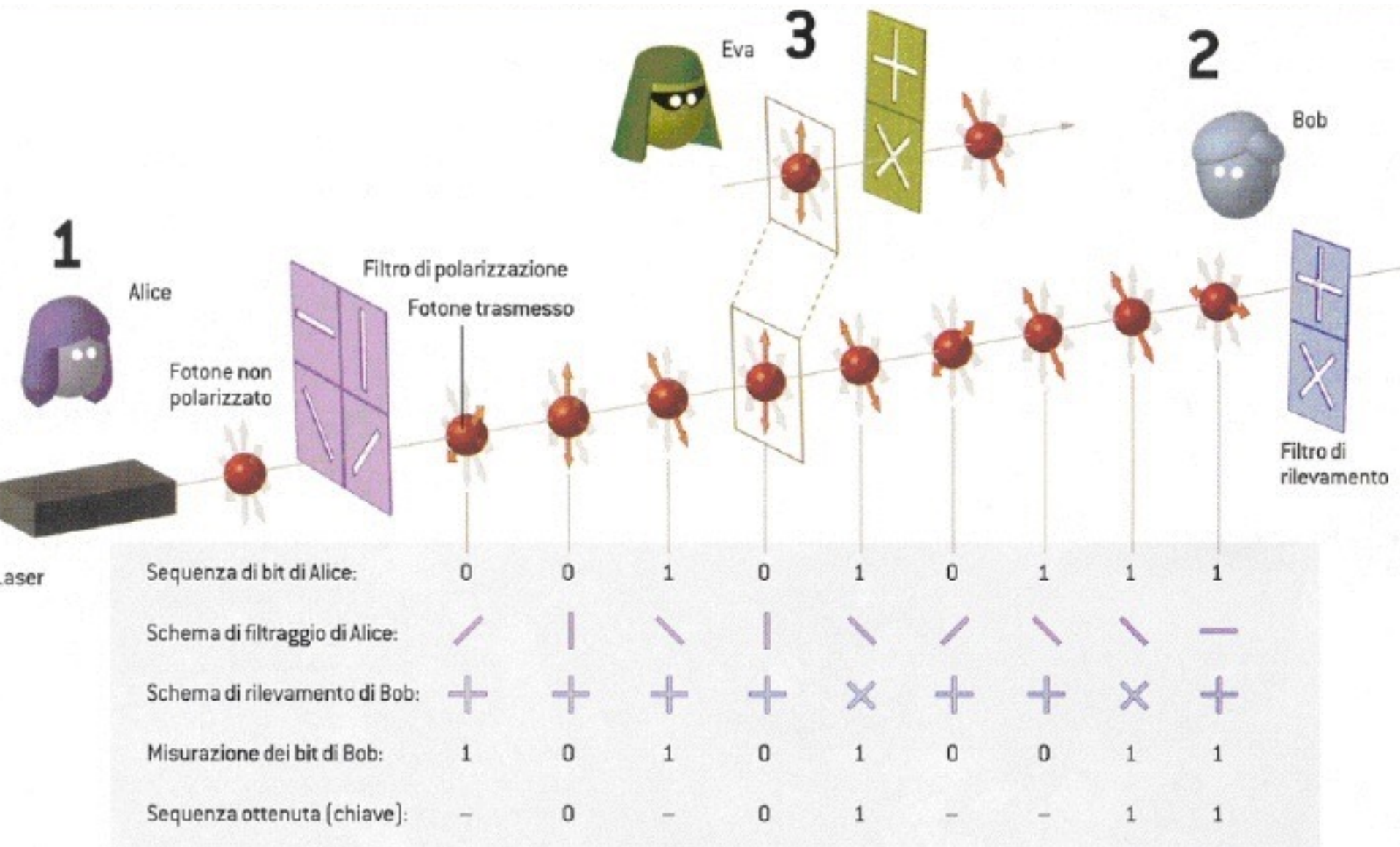


# La Crittografia Classica: Chiave Privata

Protocollo a chiave privata: scambio di chiave tramite canale sicuro!



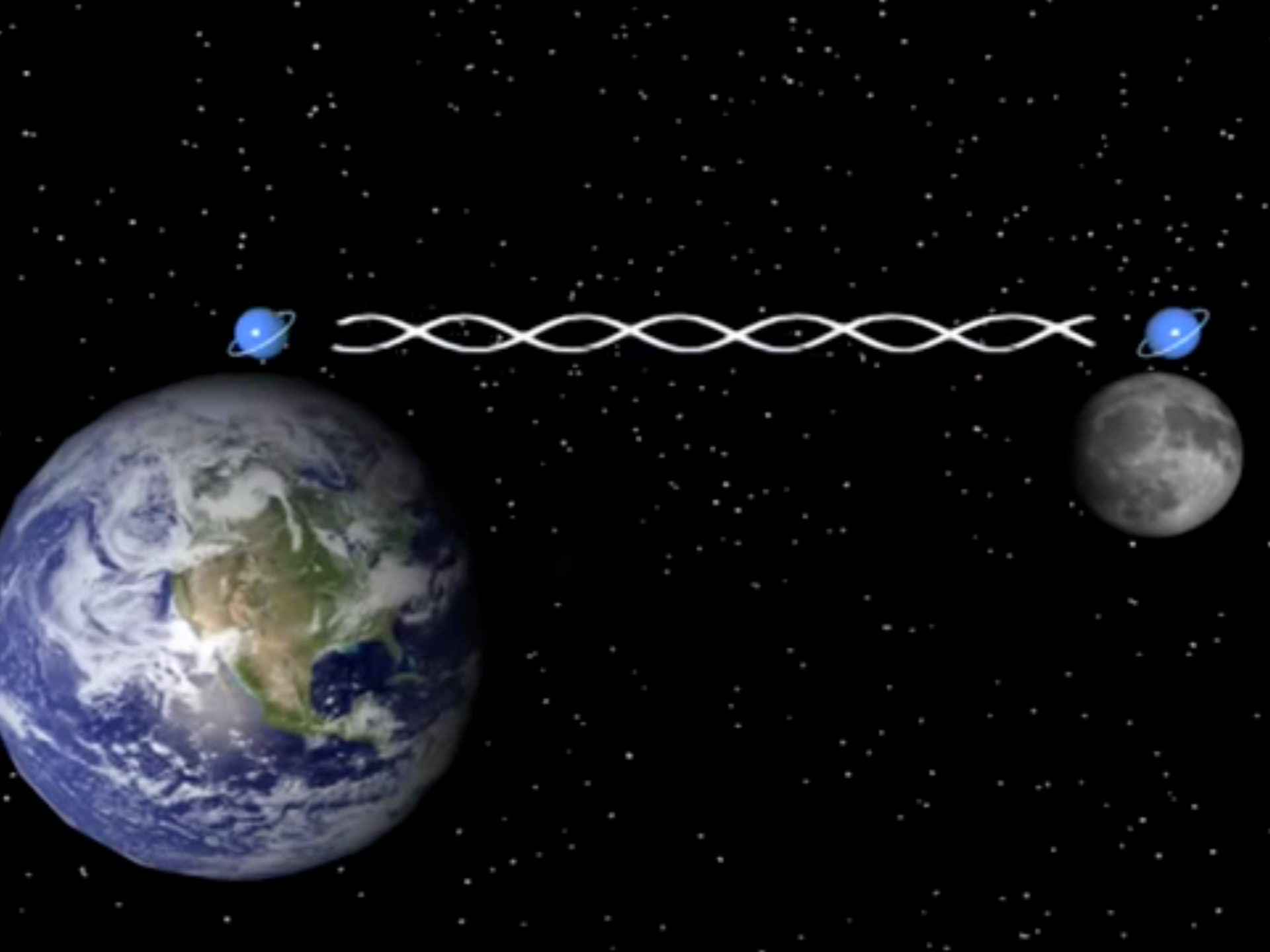
# Crittografia quantistica



# Crittografia Quantistica



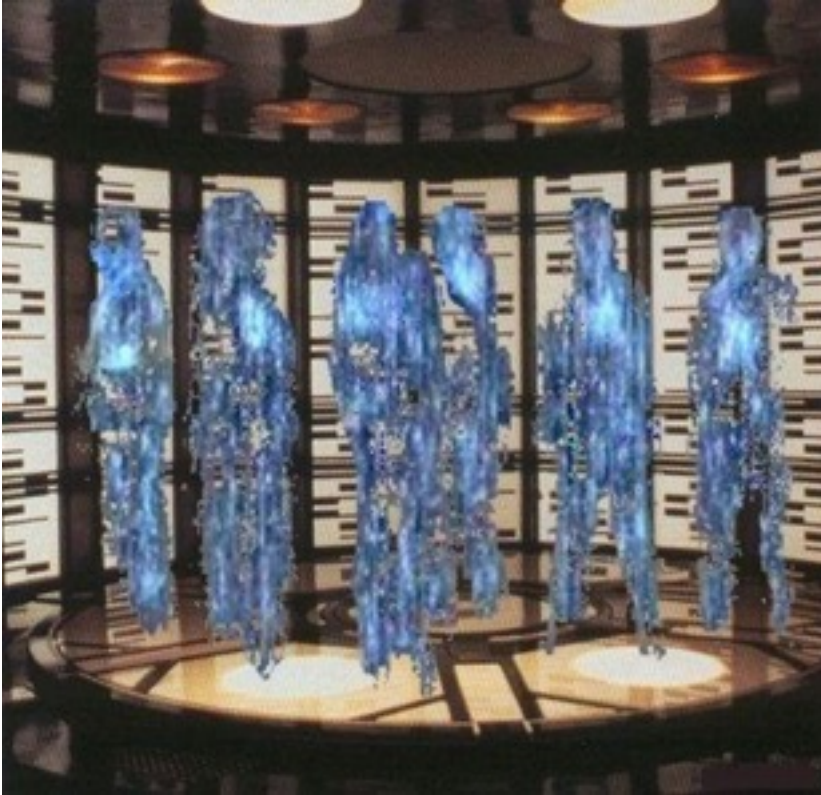
# Teleportation







**... fino al teletrasporto quantistico...**

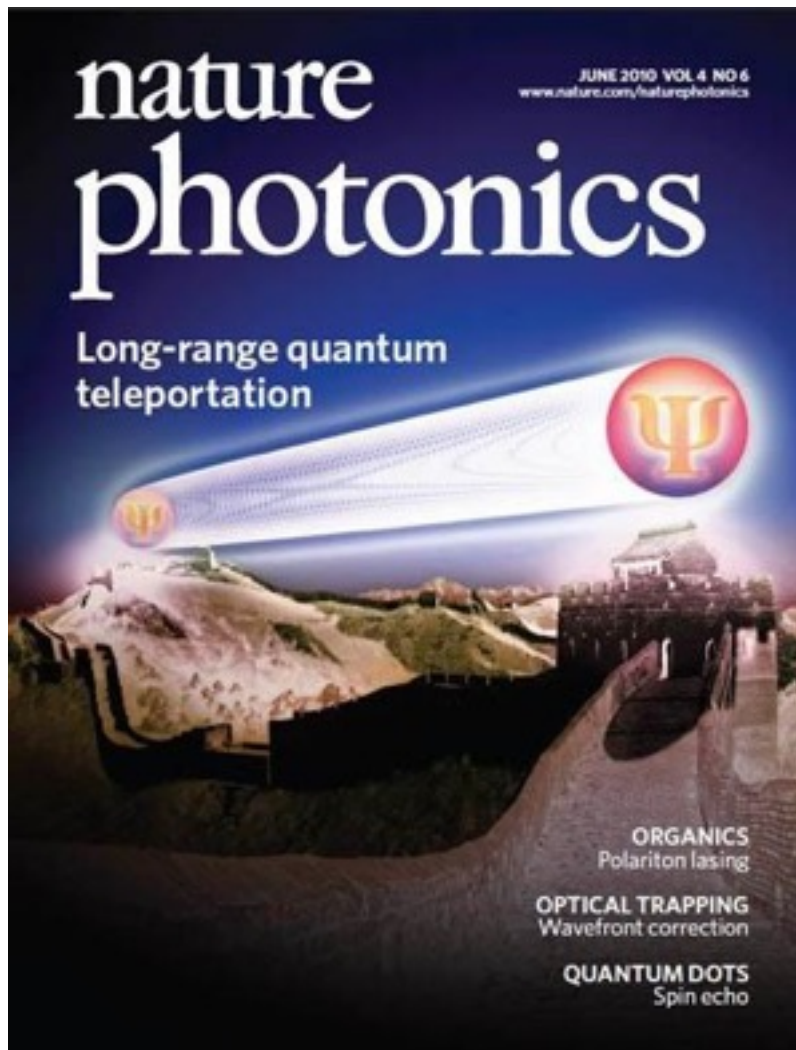


**Cosa si teletrasporta ?**

**$\Psi$**

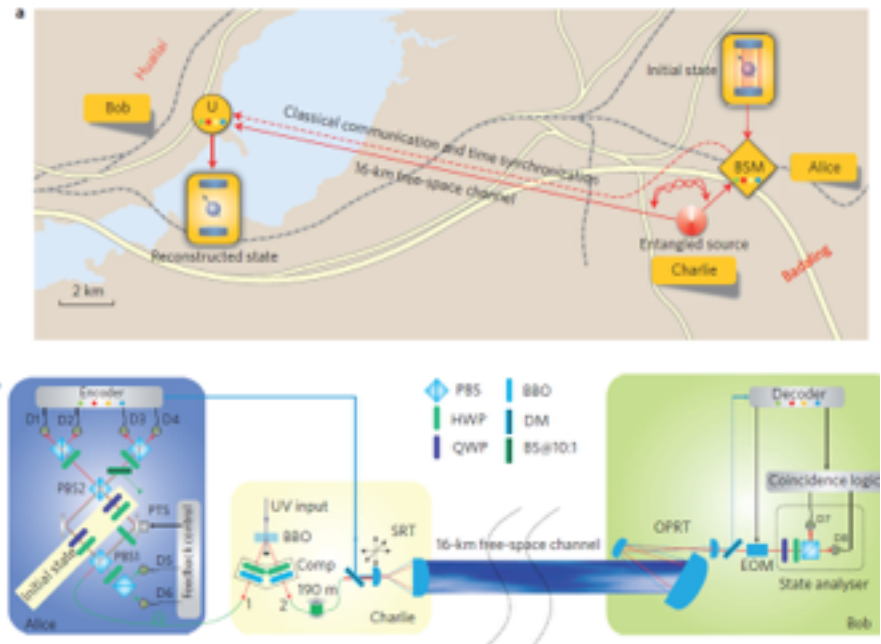
**La funzione d'onda**

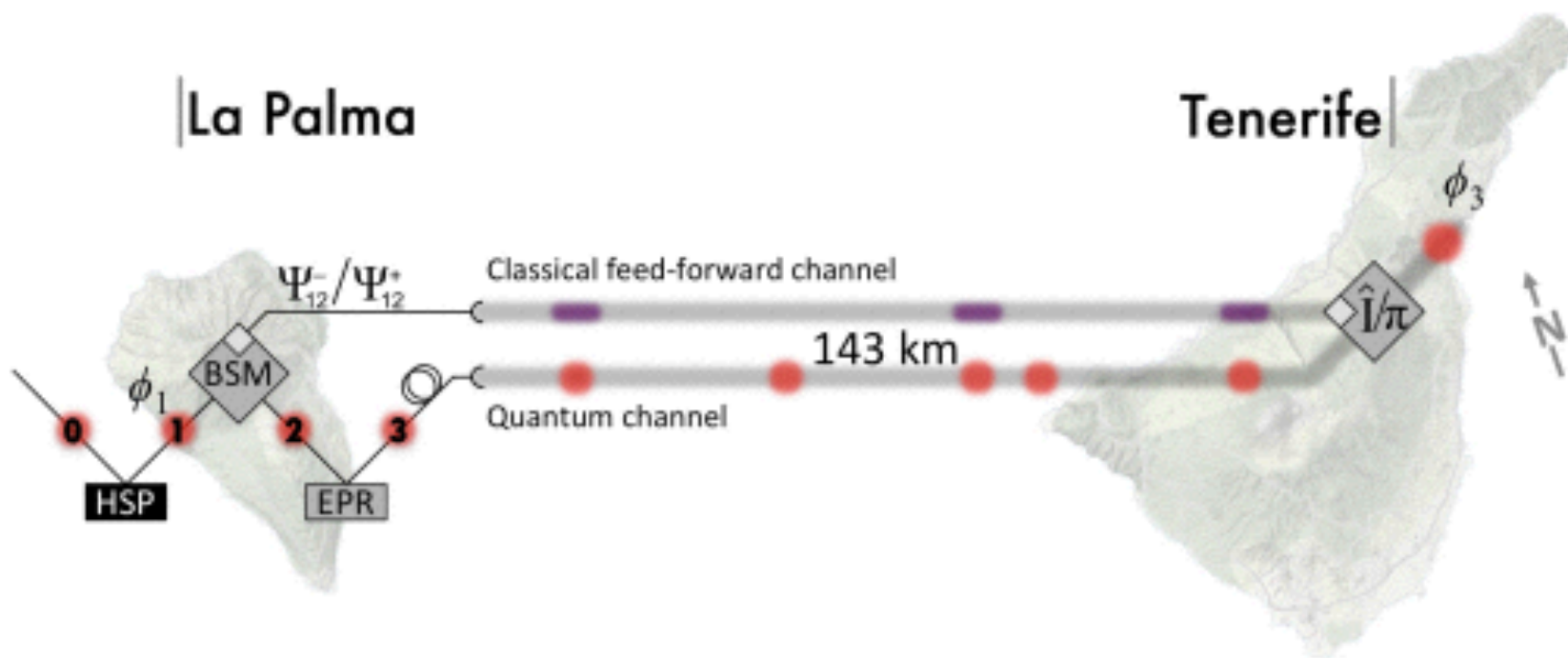
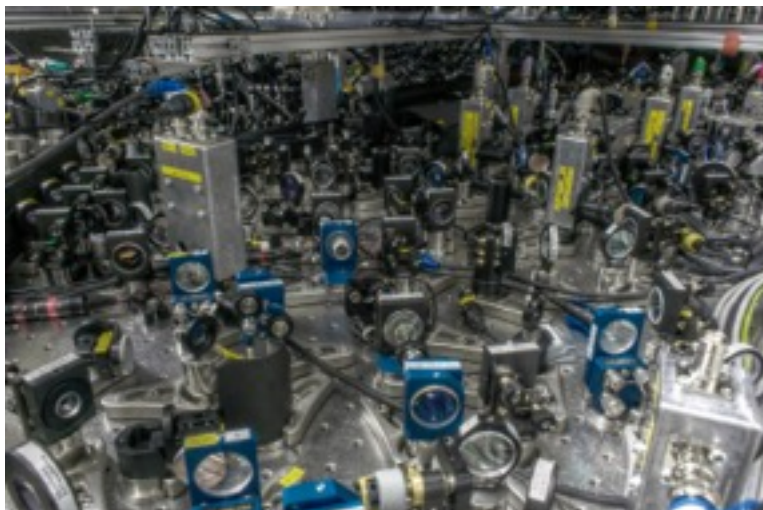
# ... fino al teletrasporto quantistico...



## Experimental free-space quantum teleportation

Xian-Min Jin<sup>1</sup>, Ji-Gang Ren<sup>1,2</sup>, Bin Yang<sup>1</sup>, Zhen-Huan Yi<sup>2</sup>, Fei Zhou<sup>2</sup>, Xiao-Fan Xu<sup>1</sup>, Shao-Kai Wang<sup>2</sup>, Dong Yang<sup>2</sup>, Yuan-Feng Hu<sup>1</sup>, Shuo Jiang<sup>2</sup>, Tao Yang<sup>1</sup>, Hao Yin<sup>1</sup>, Kai Chen<sup>1</sup>, Cheng-Zhi Peng<sup>2\*</sup> and Jian-Wei Pan<sup>1,2\*</sup>

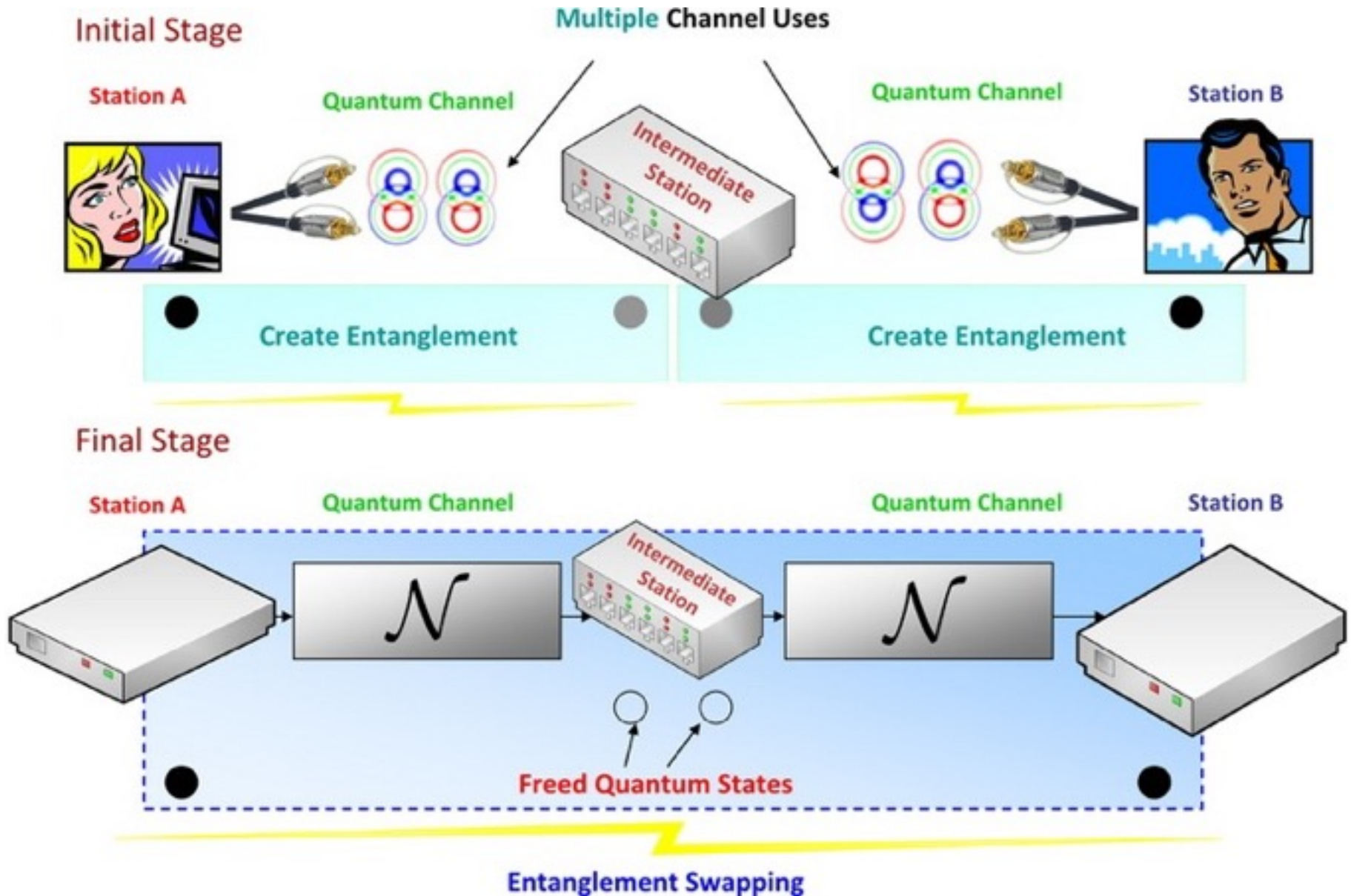




*“Il problema del teletrasporto..”*

Big Bang Theory, Serie I, Episodio 12

# *Quantum teleportation: il ripetitore quantistico*



# QUBIT (Quantum Bit)

$$\alpha|0\rangle + \beta|1\rangle$$

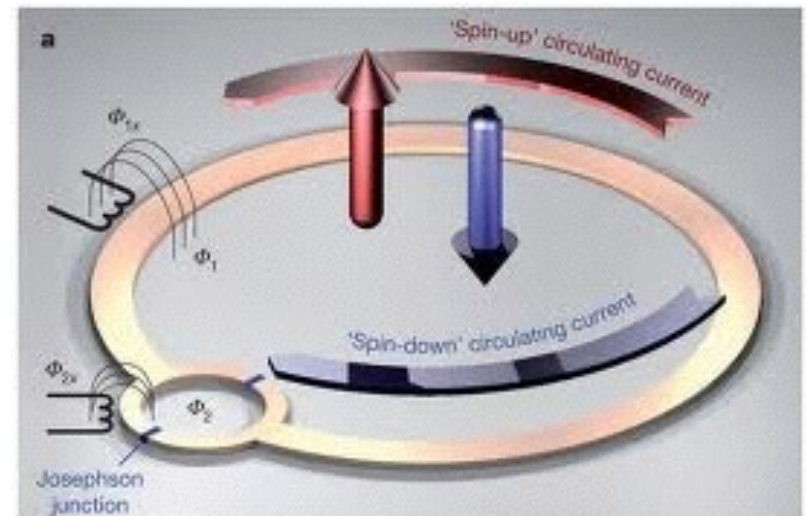
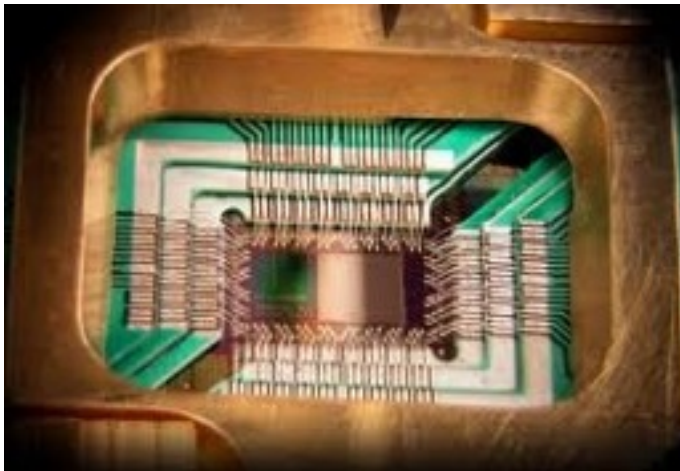
**OBIETTIVO:  
SFRUTTARE IL PARALLELISMO  
QUANTISTICO**

# D-wave: un computer quantistico commerciale...

512 qubit....

Cost: 10.000.0000 \$

bought from NASA, google..

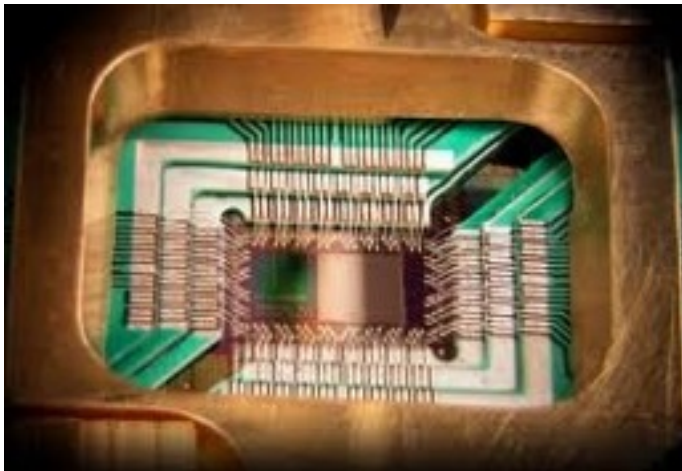


# D-wave: un computer quantistico commerciale ?!?

512 qubit....

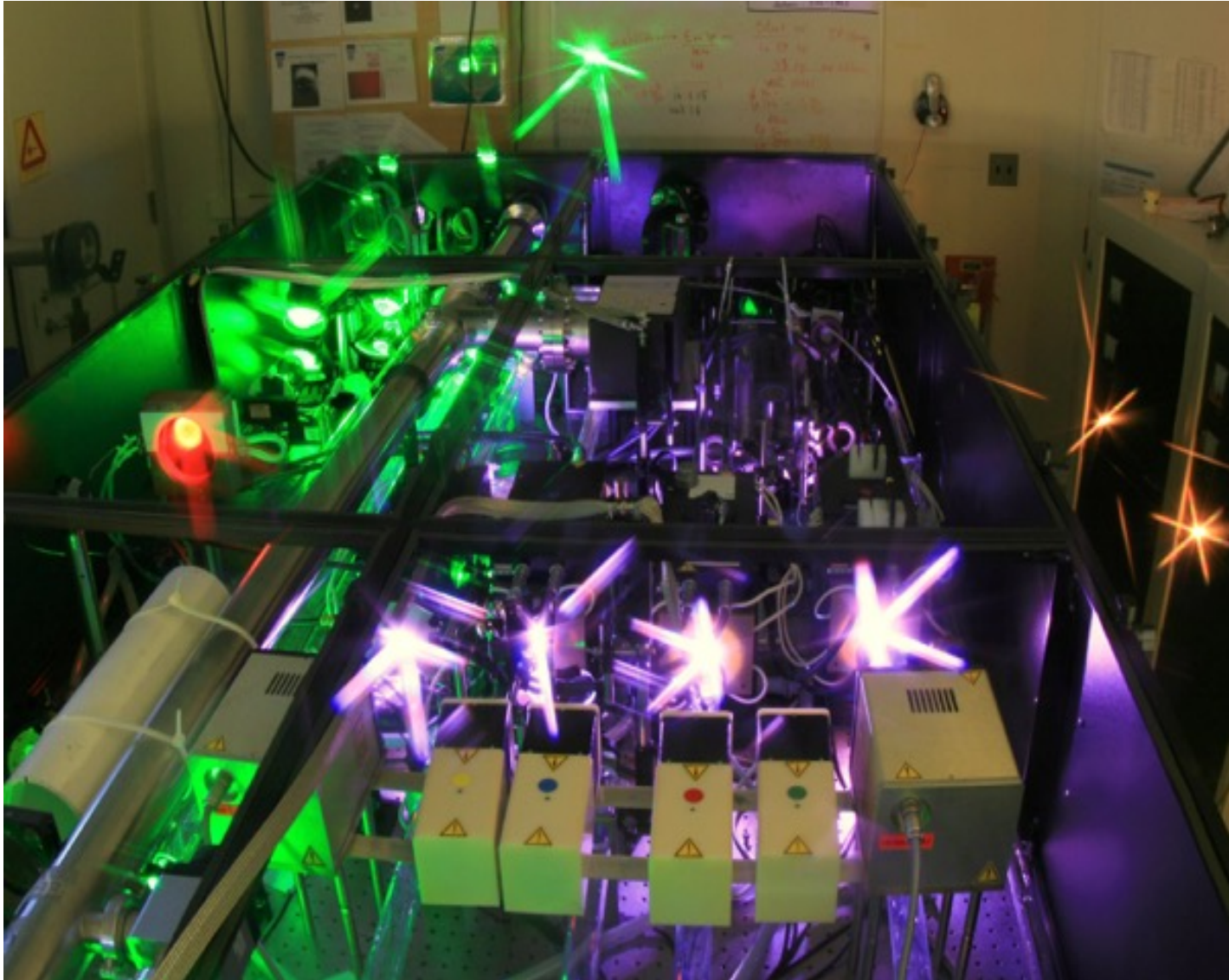
Cost: 15.000.000 \$

Bought from da NASA, google..



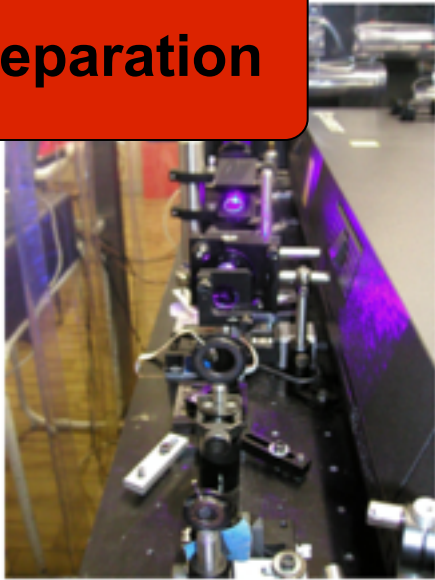
*E' "veramente" quantistico?  
E più potente di un computer  
classico (ordinario)?*

# Un computer quantistico grande così??

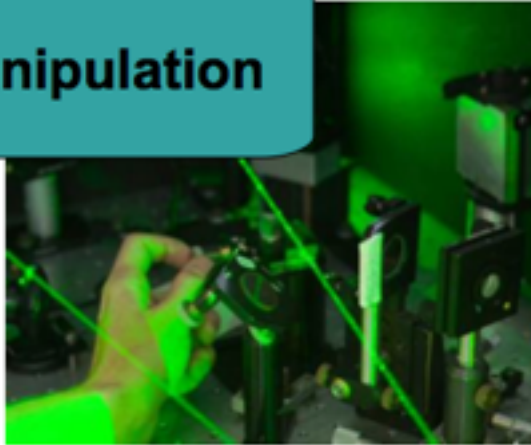


# Integrated quantum photonics

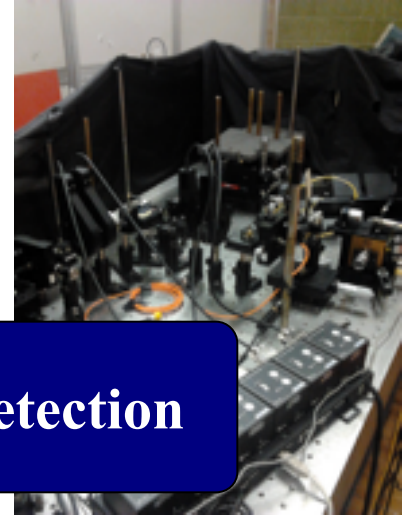
**Preparation**



**Manipulation**



**Detection**

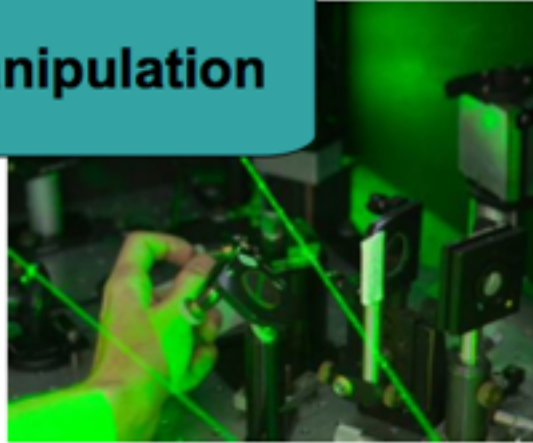


# Integrated quantum photonics

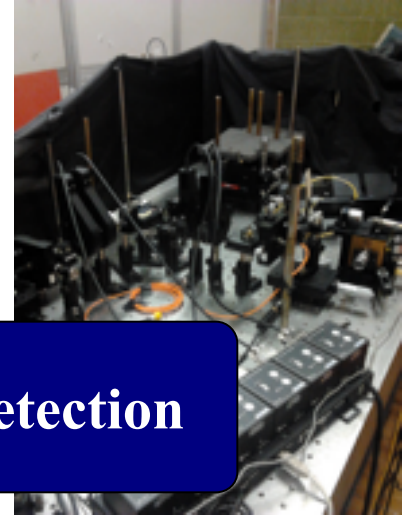
**Preparation**



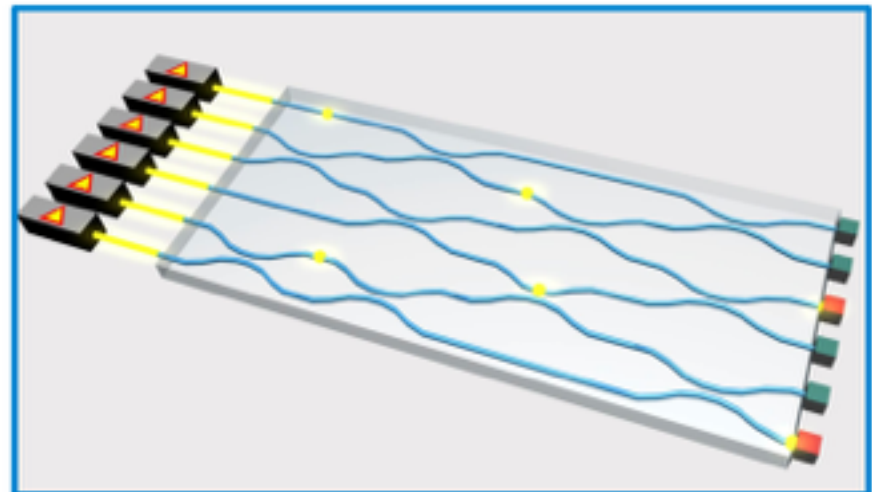
**Manipulation**



**Detection**



- Single photon sources
  - Manipulation
  - Single photon detectors
- ON THE SAME CHIP**

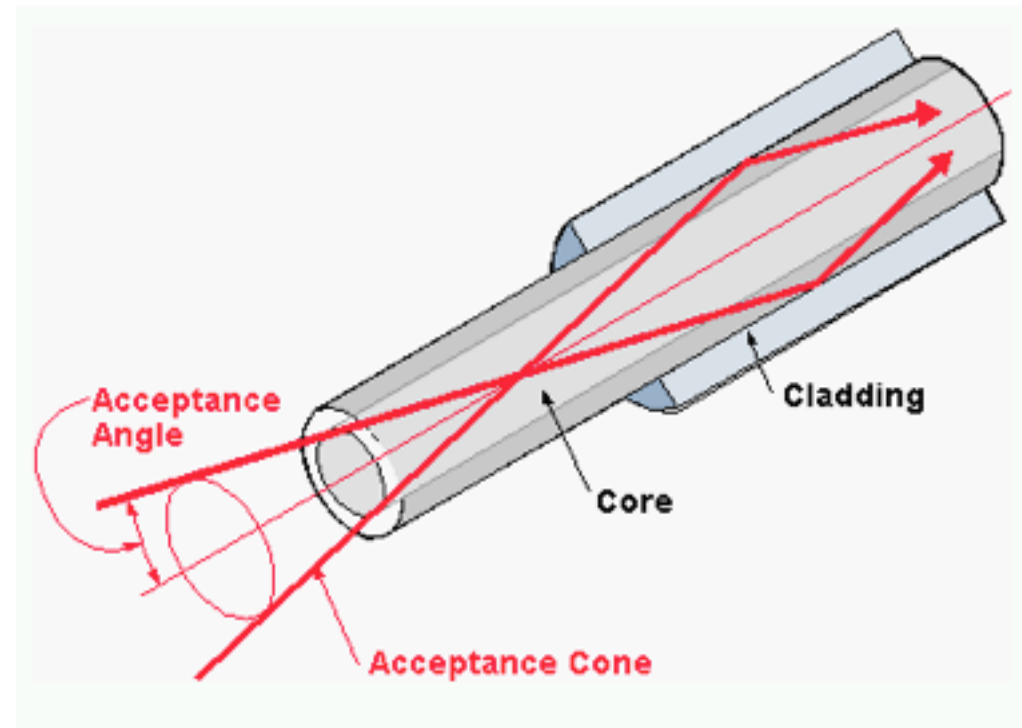


# How to guide light inside the chip ?

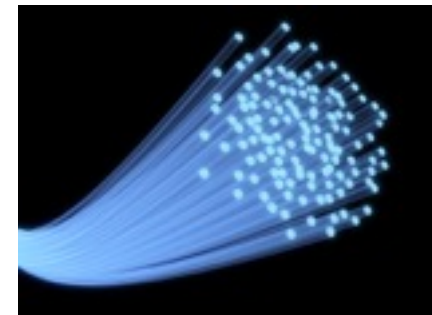
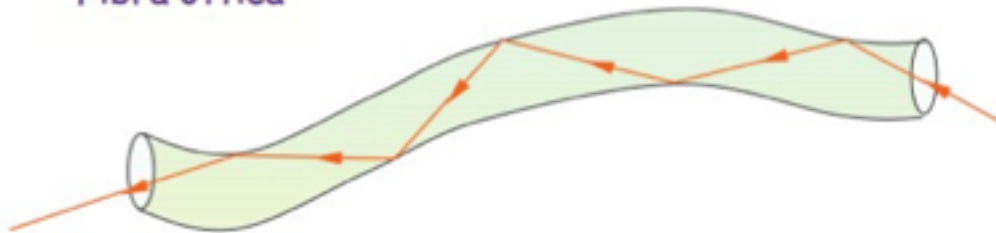
From Computer Desktop Encyclopedia  
© 1999 The Computer Language Co. Inc.

Optical fibre:

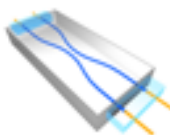
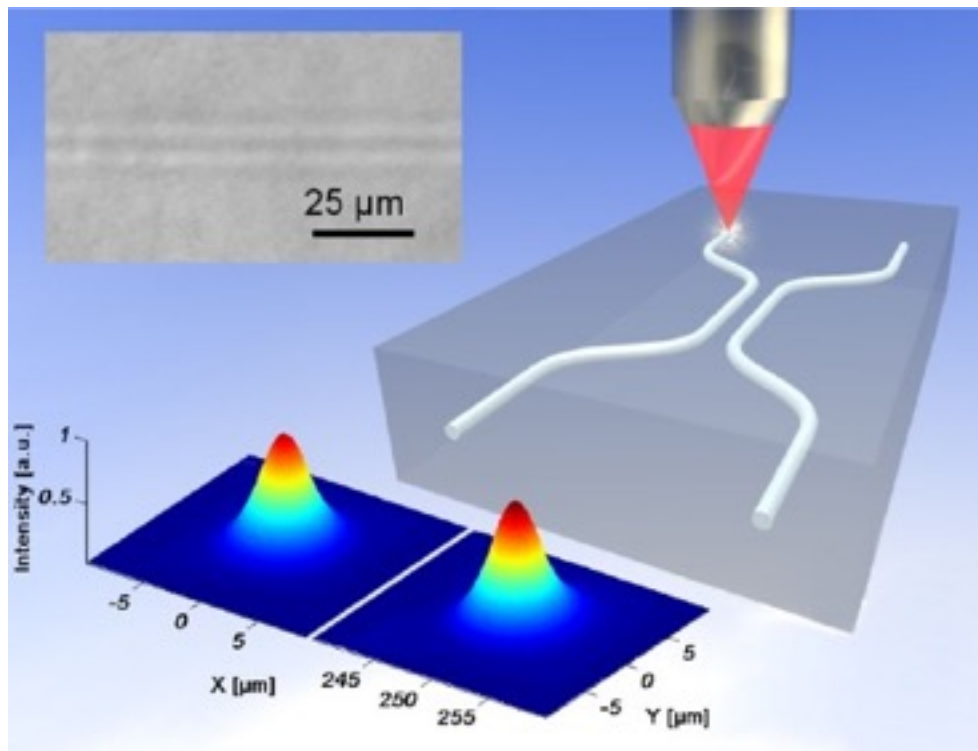
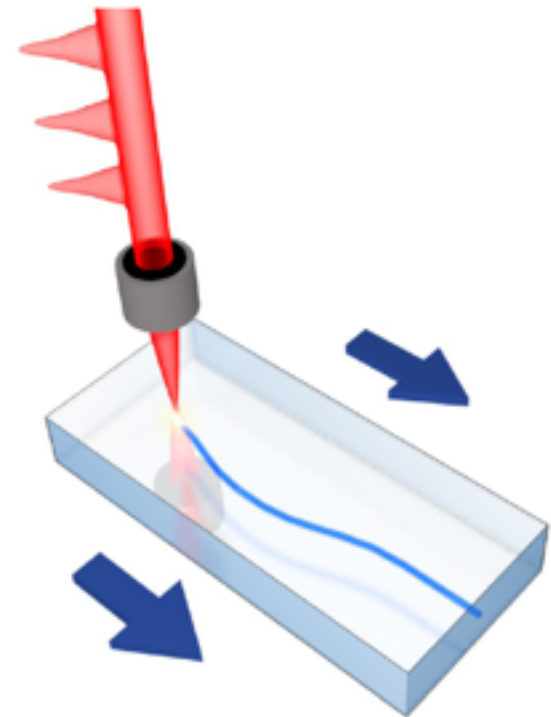
*Guide the light*



Fibra ottica

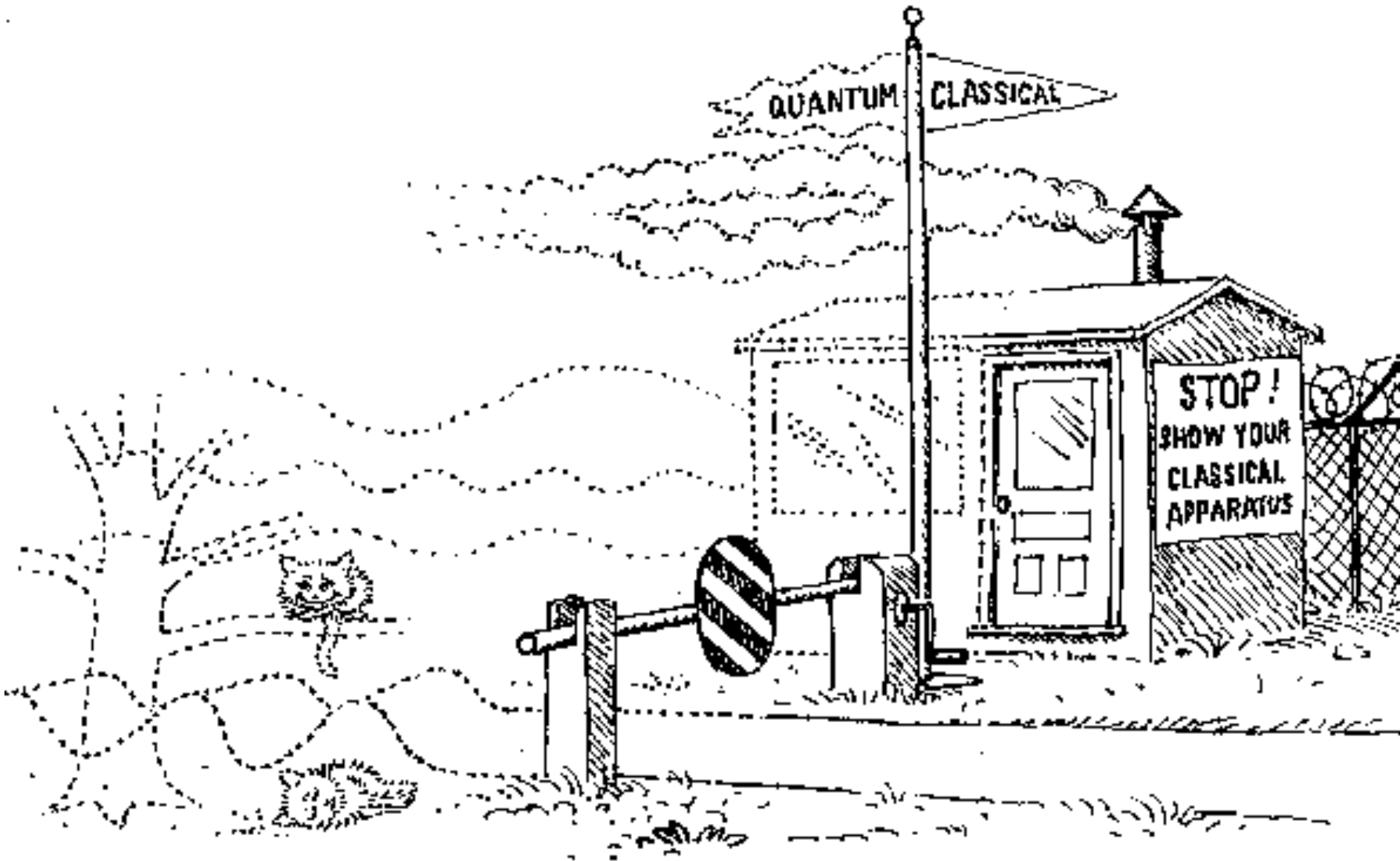


# Laser written integrated circuit





# La frontiera fra il mondo classico e quello quantistico



# Schrödinger's Cat AND THE QUANTUM STATE

BERLIN, 1935

WE WILL PERFORM  
EIN EXPERIMENT, JA?

Erwin  
Schrödinger

1887 - 1961



FIRST, WE WILL NEED ... A KAT!

KOMM, PUSSI  
PUSSI PUSSI!



ACK!



HMM. WE WILL  
USE NEWTON'S  
LAW TO GET DER KAT  
OUT OF DER TREE...

$$F = G \frac{M_1 M_2}{R^2}$$



KICK

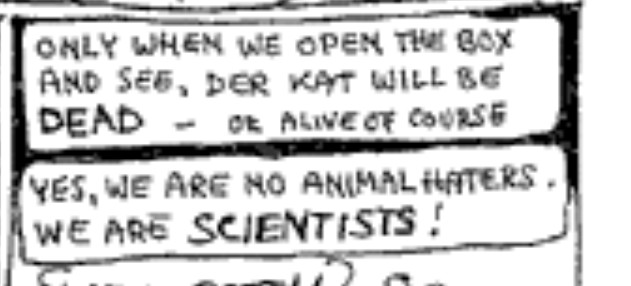
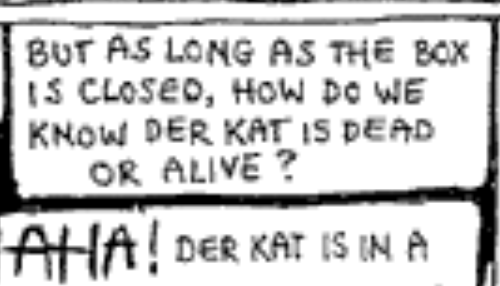
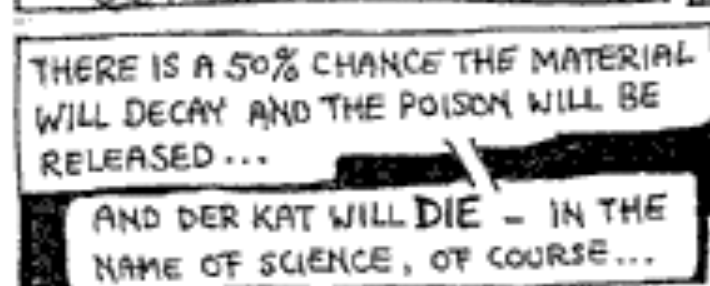


DER KAT MAY BE QUICK, BUT EINSTEIN'S  
LAW SHOWS US THAT EVERYTHING IS  
RELATIVE ...

MROW!

$$E = MC^2$$





# Thank you!



## QUANTUM OPTICS GROUP

Dipartimento di Fisica, Sapienza Università di Roma



[www.3dquest.eu](http://www.3dquest.eu)

<http://quantumoptics.phys.uniroma1.it>

[fabio.sciarrino@uniroma1.it](mailto:fabio.sciarrino@uniroma1.it)

Twitter: @FabioSciarrino



*Enjoy life, enjoy quantum!*