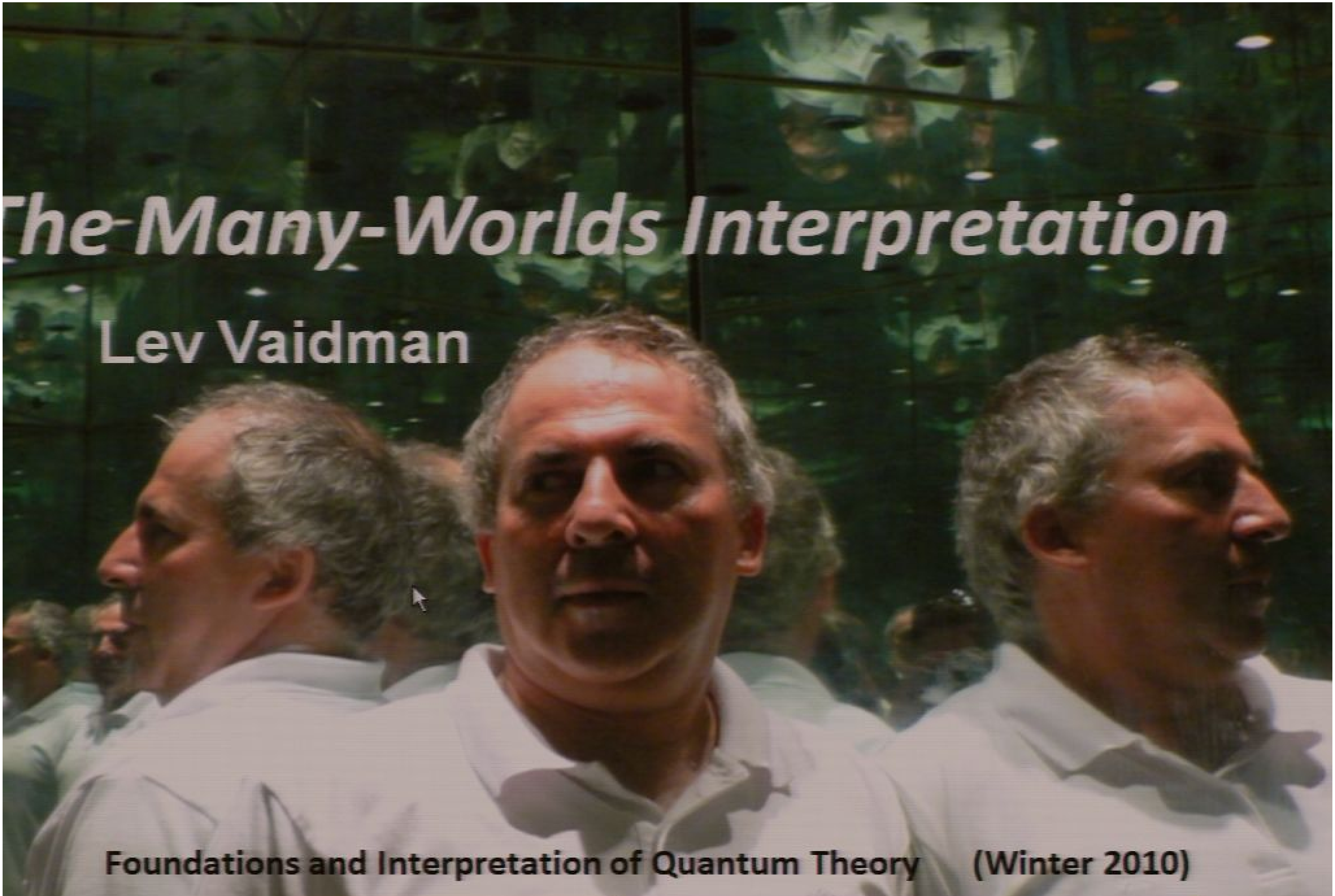
Title: Foundations and Interpretation of Quantum Theory - Lecture 16

Date: Mar 16, 2010 02:30 PM

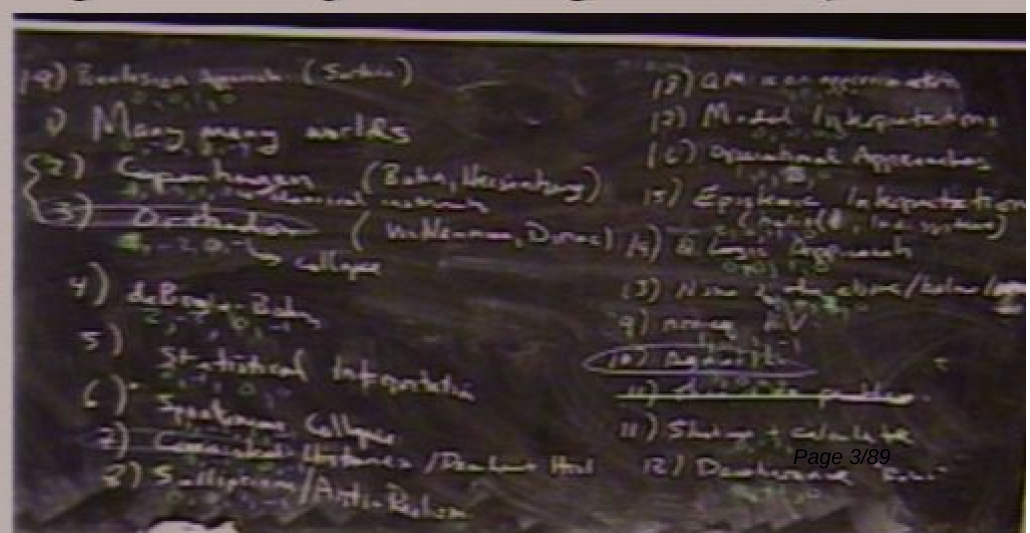
URL: http://pirsa.org/10030006

Abstract:


The Many-Worlds Interpretation
Lev Vaidman
Foundations and Interpretation of Quantum Theory (Winter 2010)

erpretation	Students For	Students Against	Student Total	Researchers For	Researchers Against	Researcher Total	Overall Total
oenhagen and/or hodox	4	-5	-1	1	-1	0	-1
Broglie-Bohm (and ensions)	3	-3	0	1	-2	-1	-1
ny Worlds (and coherence)	1	-6	-5	1	-3	-2	-7 ?!
tistical/Epistemic erpretation	4	-1	3	1	0	1	4
namical Collapse proaches	1	-2	-1	1	0	1	0
nsistent/Decohere Histories	3	-1	2	0	-1	-1	1
nostics and erationalists	4	0	4	3	0	3	7
antum Mechanics n Approximation	1	0	1	0	0	0	1
ut up and culate!"	0	-3	-3	0	0	0	-3
lipsism	0	0	0	0	-1	-1	-1
ne of the Above her)	1	0	1	3	0	3	4

04/05/2005



undations and Interpretation of uantum Theory (Winter 2005)

erloo IQC

Quantum Optics Lab

The Quantum World Splitter

e MWI Split

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.

he Quantum World Splitter

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

Quantum Optics Lab

The Quantum World Splitter

…e MWI Split

Welcome To The Quantum World Splitter

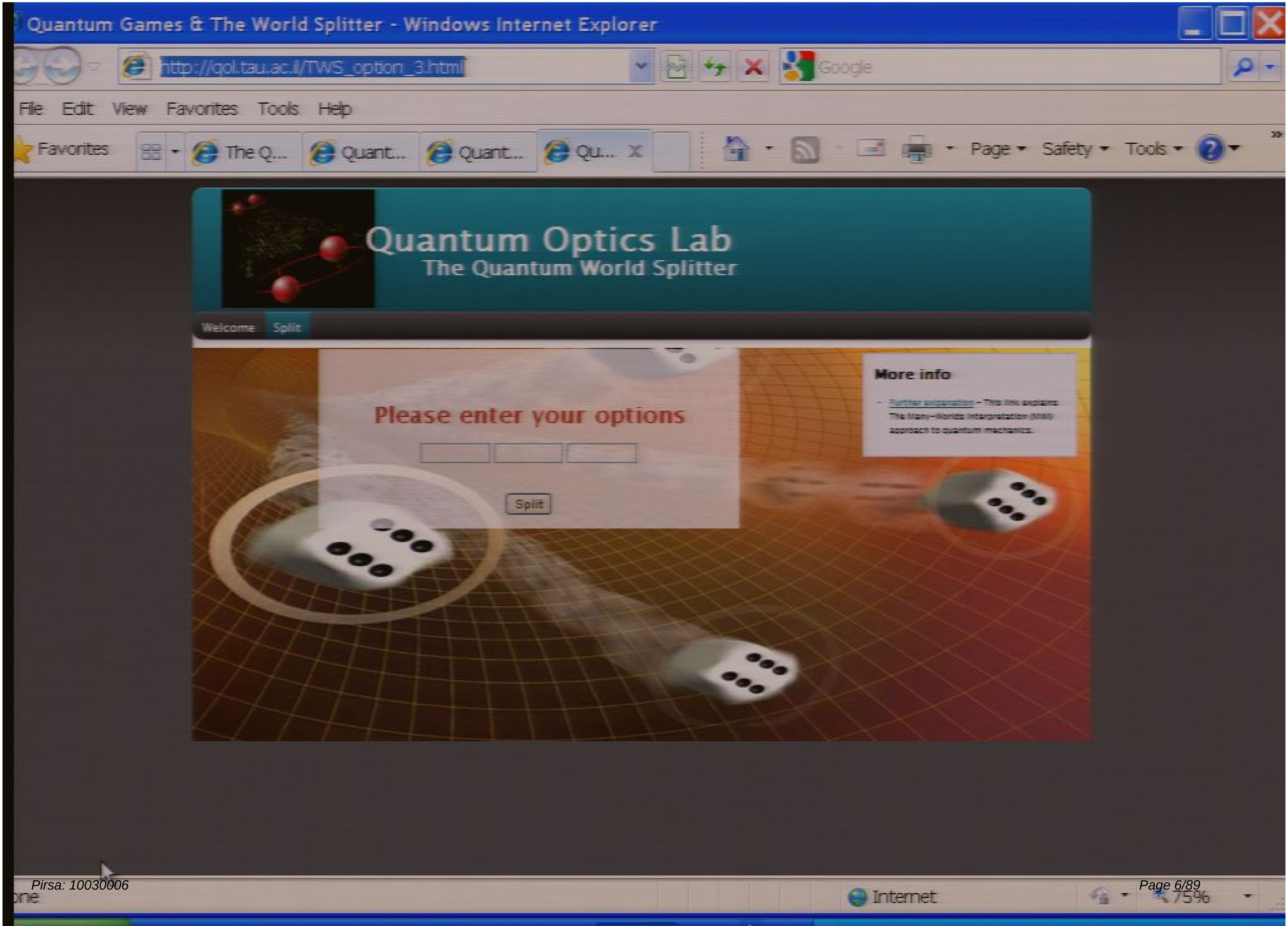
You now have a control over a Quantum Optics Laboratory In Tel Aviv University.
When you push SPLIT you will preform a quantum experiment with single photons.
You can choose from splitting 2 up to 6 worlds, they will be created with a copy of you in each world.

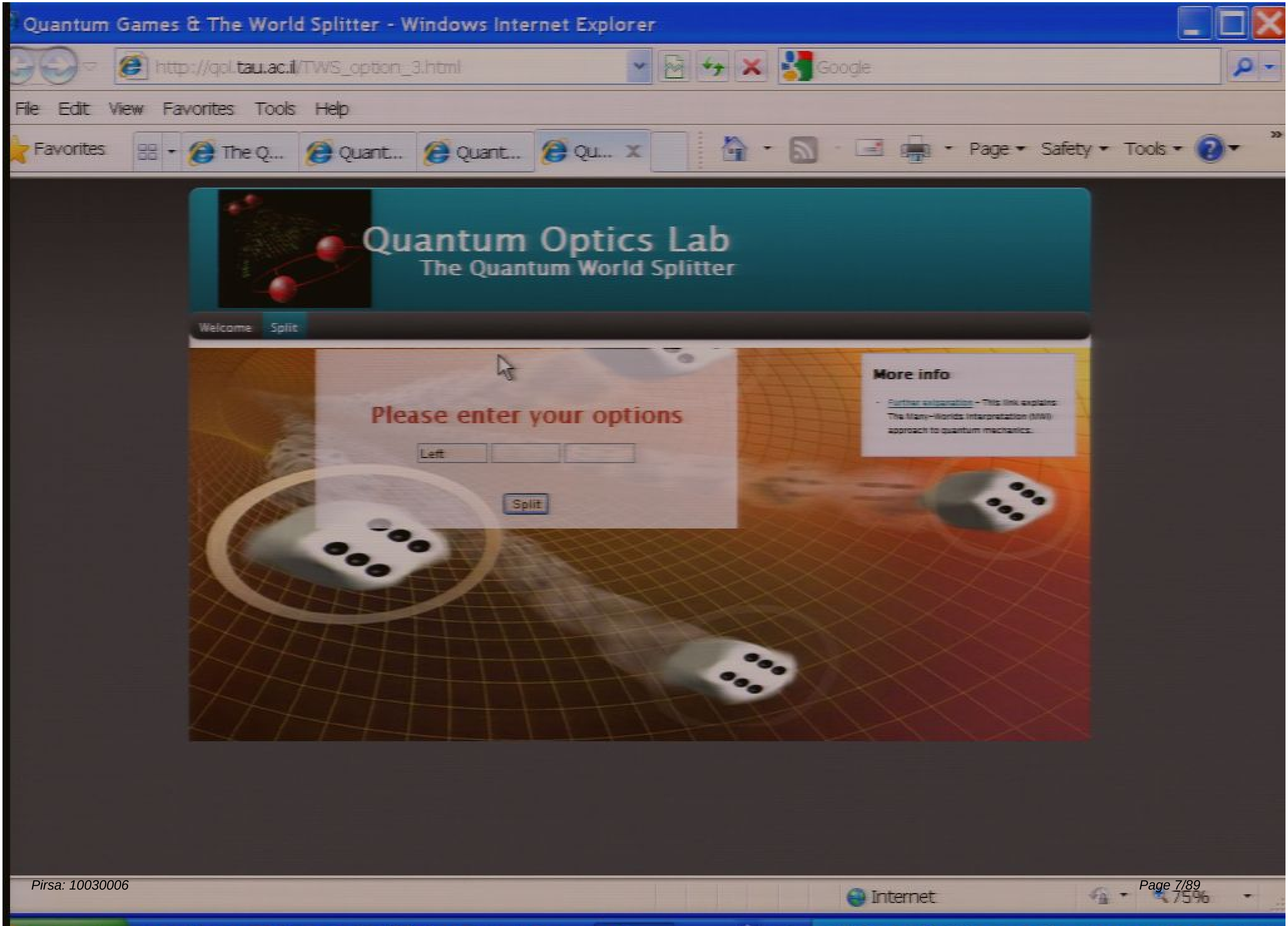
If you want to choose between several options in your life, now you can do them all at once.

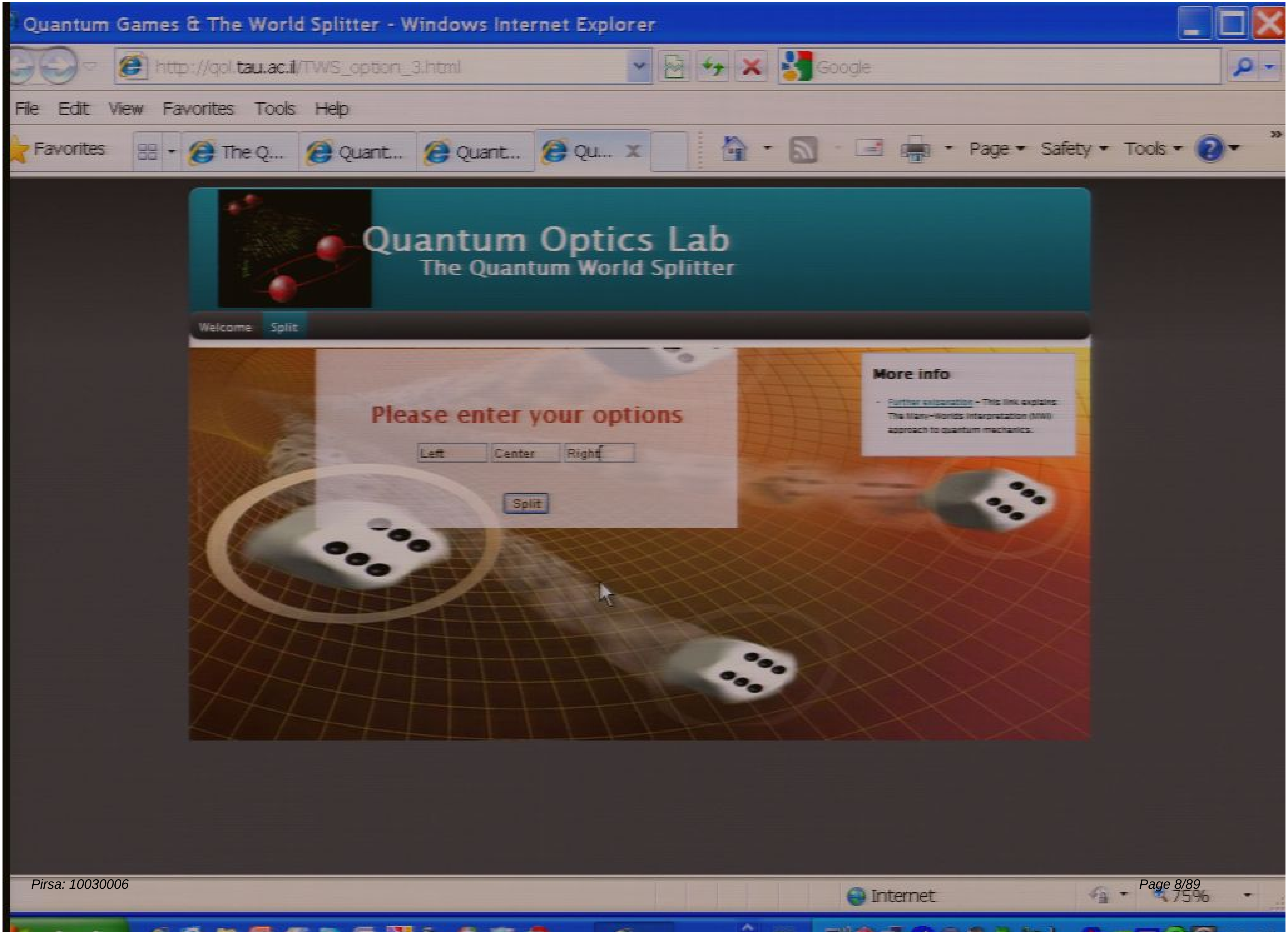
he Quantum World Splitter

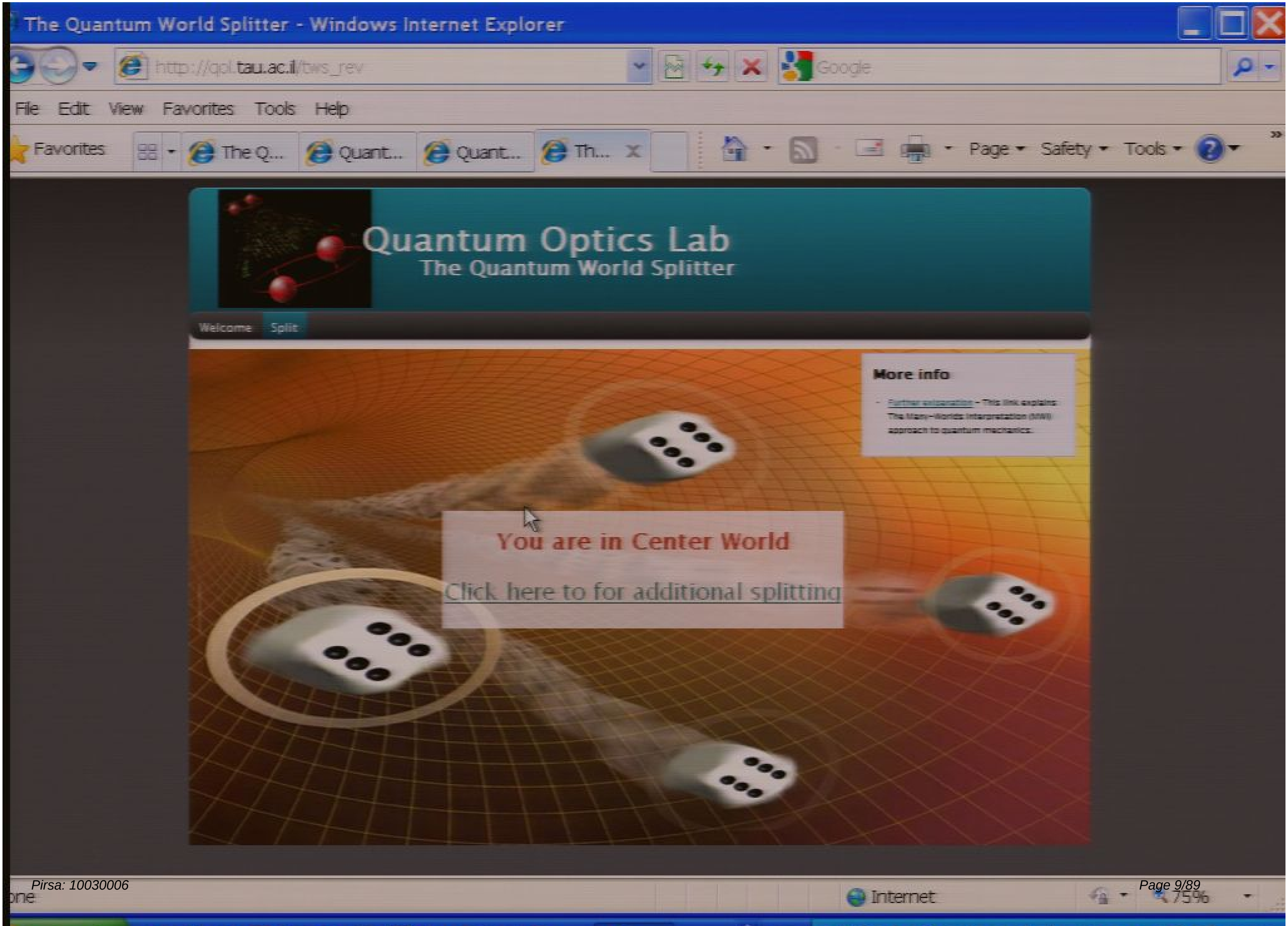
Choose how many worlds you want to split by pressing one of the red dice faces.

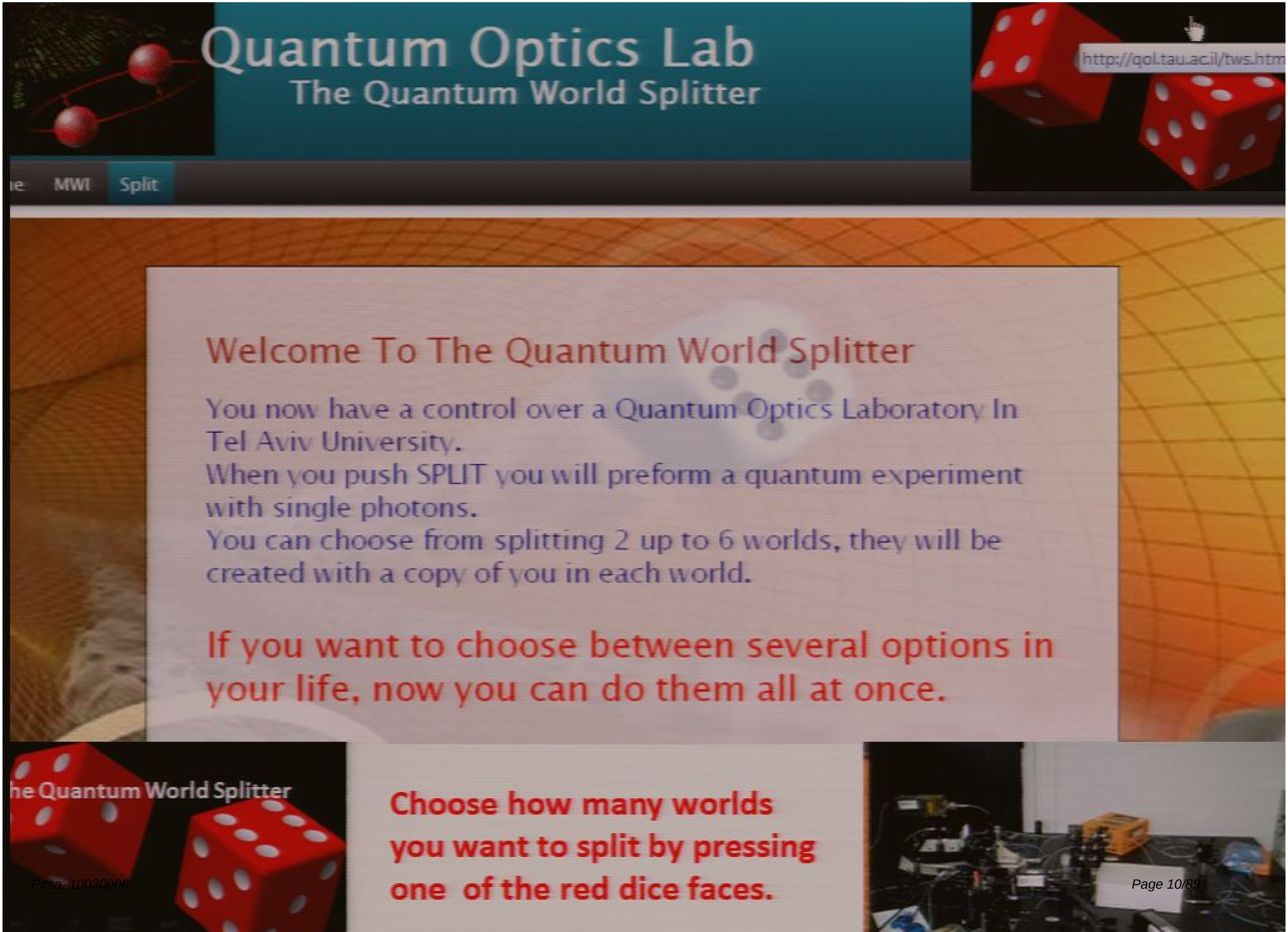
http://qol.tau.ac.il/TWS_option_3.html


Quantum Games & The World Splitter - Windows Internet Explorer
http://qol.tau.ac.il/TWS_option_3.html
Google
File Edit View Favorites Tools Help
Favorites
The Q...
Quant...
Quant...
Qu...
Page
Safety
Tools
Quantum Optics Lab
The Quantum World Splitter
Welcome
Split
More info
Please enter your options
Split
Internet
75%


Quantum Games & The World Splitter - Windows Internet Explorer
http://qol.tau.ac.il/TWS_option_3.html
File Edit View Favorites Tools Help
Favorites
Page Safety Tools
Quantum Optics Lab
The Quantum World Splitter
Welcome
Split
Please enter your options
Left
Split
More info
Internet
75%


Quantum Games & The World Splitter - Windows Internet Explorer
http://qol.tau.ac.il/TWS_option_3.html
Google
File Edit View Favorites Tools Help
Favorites
The Q...
Quant...
Quant...
Qu...
Page
Safety
Tools
Quantum Optics Lab
The Quantum World Splitter
Welcome
Split
More info
Please enter your options
Left
Center
Right
Split
Internet
75%


The Quantum World Splitter - Windows Internet Explorer
http://qol.tau.ac.il/tws_rev
Google
File Edit View Favorites Tools Help
Favorites
The Q...
Quant...
Quant...
Th...
Page
Safety
Tools
Quantum Optics Lab
The Quantum World Splitter
Welcome
Split
More info
You are in Center World
Click here to for additional splitting
Internet


Quantum Optics Lab
The Quantum World Splitter
http://qol.tau.ac.il/tws.htm
MWI
Split
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.
he Quantum World Splitter
Choose how many worlds you want to split by pressing one of the red dice faces.


All is Ψ


All is Ψ

A superior statement about the objective characteristics of our quantum world, of the things in it, would contain <u>no</u> $|\Psi\rangle$'s at all.

Really, none!

Hope: Today’s physics explains all what we see.

Hope: Today's physics explains all what we see.

Big hope: Today's physics explains All.

Hope: Today's physics explains all what we see.

Big hope: Today's physics explains All.

If ψ is not All, what is?

Hope: Today's physics explains all what we see.

Big hope: Today's physics explains All.

If ψ is not All, what is?

Bohr (SEP): The quantum mechanical formalism does not provide physicists with a 'pictorial' representation: the ψ-function does not, as Schrödinger had hoped, represent a new kind of reality.
Instead, as Born suggested, the square of the absolute value of the ψ-function expresses a probability amplitude for the outcome of a measurement.

Hope: Today's physics explains all what we see.

Big hope: Today's physics explains All.

If ψ is not All, what is?

Bohr (SEP): The quantum mechanical formalism does not provide physicists with a 'pictorial' representation: the ψ-function does not, as Schrödinger had hoped, represent a new kind of reality. Instead, as Born suggested, the square of the absolute value of the ψ-function expresses a probability amplitude for the outcome of a measurement.

Bohr and today's majority of physicists gave up the hope

I think, we should not.

Hope: Today's physics explains all what we see.

Big hope: Today's physics explains All.

If ψ is not All, what is?

Bohr (SEP): The quantum mechanical formalism does not provide physicists with a 'pictorial' representation: the ψ-function does not, as Schrödinger had hoped, represent a new kind of reality. Instead, as Born suggested, the square of the absolute value of the ψ-function expresses a probability amplitude for the outcome of a measurement.

Bohr and today's majority of physicists gave up the hope

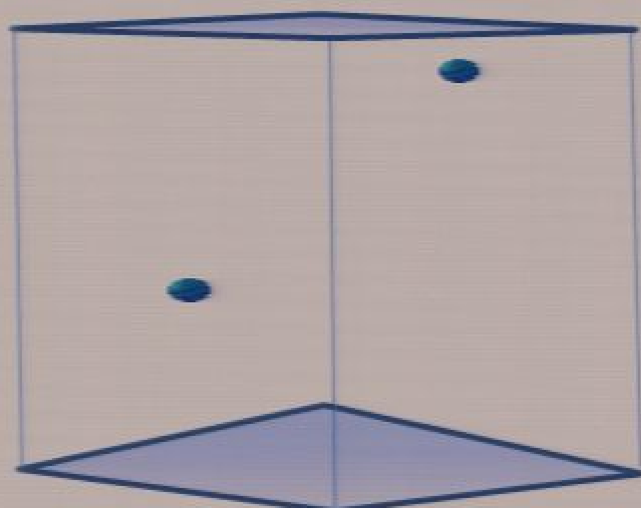
I think, we should not.

> "Of course the main goal of science is to predict and control phenomena... But we also want to understand how Nature works."
>
> -Joseph Emerson, Lecture 1


All is Ψ


All

All



All is a closed system which can be observed

All

All is a closed system which might include an observer which can be observed

All

All is a closed system which might include an observer which can be observed

What is ψ ?

There is no sharp answer. Theoretical physicists are very flexible in adapting their tools, and no axiomization can keep up with them. But it is fair to say that there are two core ideas of quantum field theory.

First: The basic dynamical degrees of freedom are operator functions of space and time- quantum fields.

Second: The interaction of these fields are local in space and time.

F. Wilczek (in Compendium of Quantum Physics, 2009)

All

All is a closed system which might include an observer which can be observed

What is ψ ?

There is no sharp answer. Theoretical physicists are very flexible in adapting their tools, and no axiomization can keep up with them. But it is fair to say that there are two core ideas of quantum field theory.

First: The basic dynamical degrees of freedom are operator functions of space and time- quantum fields.

Second: The interaction of these fields are local in space and time.

F. Wilczek (in Compendium of Quantum Physics, 2009)

What is ψ ?

There is no sharp answer. Theoretical physicists are very flexible in adapting their tools, and no axiomization can keep up with them. But it is fair to say that there are two core ideas of quantum field theory.

First: The basic dynamical degrees of freedom are operator functions of space and time- quantum fields.

Second: The interaction of these fields are local in space and time.

F. Wilczek (in Compendium of Quantum Physics, 2009)

$$\Psi(A_\mu^a(\vec{r}),\psi_\mu^a(\vec{r}))$$

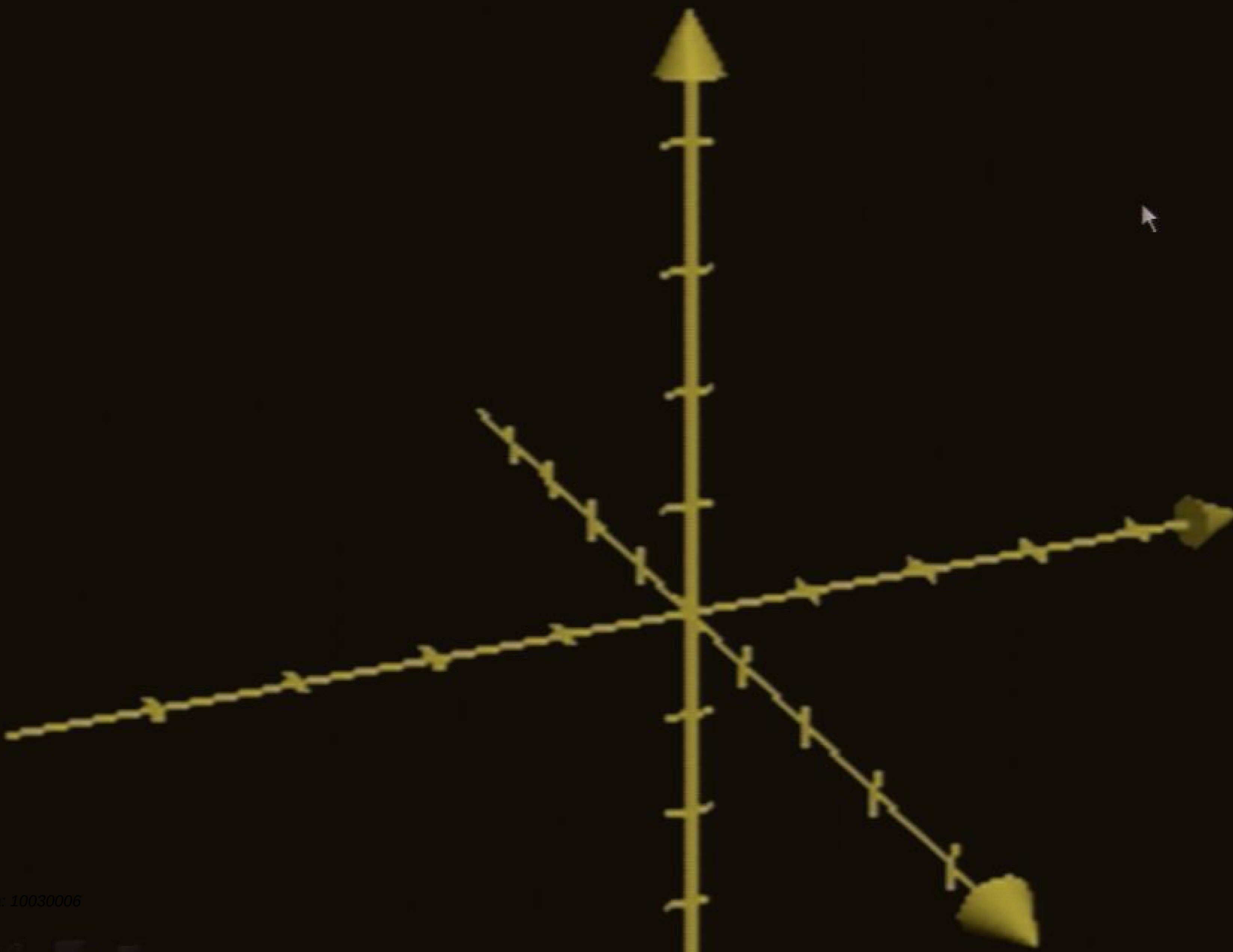
What is ψ ?

There is no sharp answer. Theoretical physicists are very flexible in adapting their tools, and no axiomization can keep up with them. But it is fair to say that there are two core ideas of quantum field theory.
First: The basic dynamical degrees of freedom are operator functions of space and time- quantum fields.
Second: The interaction of these fields are local in space and time.

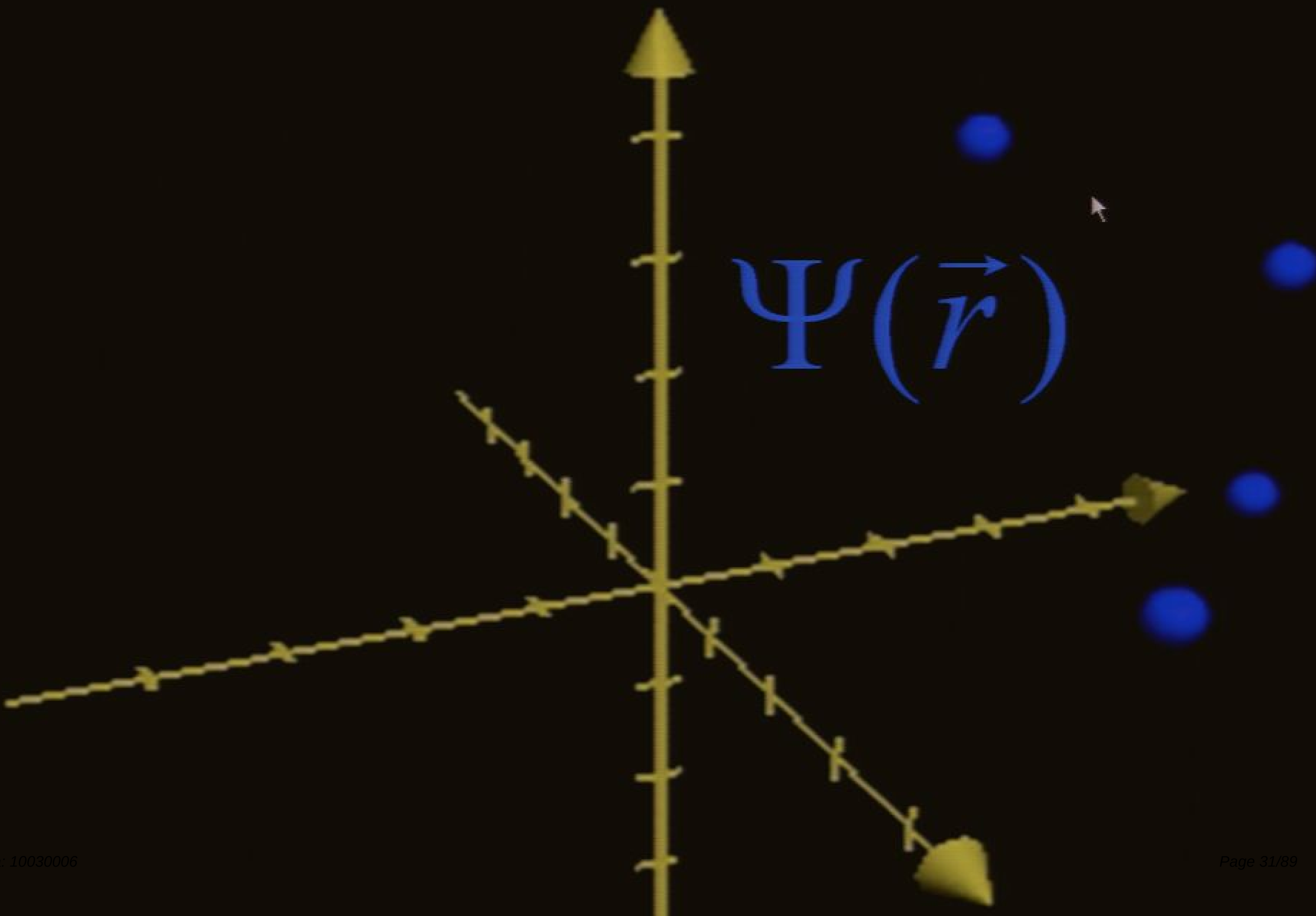
F. Wilczek (in Compendium of Quantum Physics, 2009)

$$\Psi(A_\mu^a(\vec{r}), \psi_\mu^a(\vec{r})) \qquad \Psi(\vec{r})$$

Space is taken for granted



Space is taken for granted



There is no collapse

There is no collapse

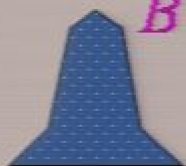
All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness

A

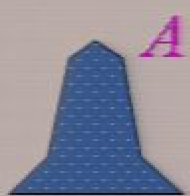
$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|a\rangle + |b\rangle\right)$$



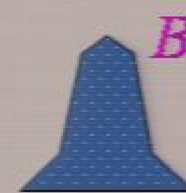
B

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness



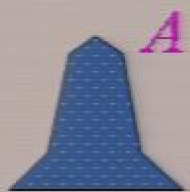
$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|a\rangle + |b\rangle\right)$$



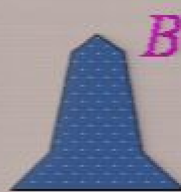
MEASUREMENT IN *A* : $P_A = ?$

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness



$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|a\rangle + |b\rangle\right)$$



MEASUREMENT IN *A* : $P_A = ?$

$P_A = 1$

OR

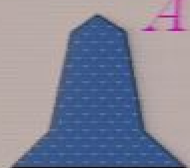
$P_A = 0$

random event

by definition

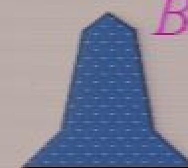
There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness
action at a distance



A

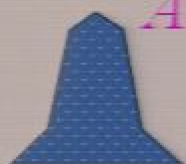
$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|a\rangle + |b\rangle\right)$$



B

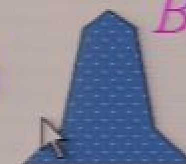
There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness, action at a distance



A

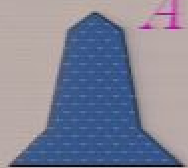
$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|a\rangle + |b\rangle\right) = \frac{1}{\sqrt{2}}\left(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B\right)$$



B

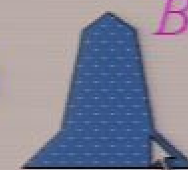
There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ randomness, action at a distance



A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

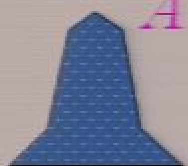


B

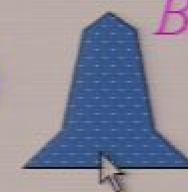
$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ **randomness, action at a distance**


A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A|0\rangle_B + |0\rangle_A|1\rangle_B)$$

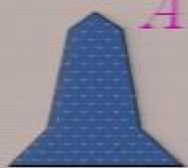

B

$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

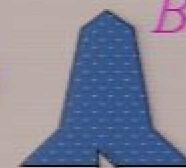
MEASUREMENT IN *A*: $P_A = ?$

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ **randomness, action at a distance**



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

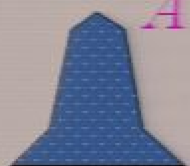
MEASUREMENT IN *A*: $P_A = ?$

$$P_A = 1$$

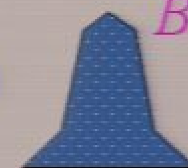
$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ **randomness, action at a distance**


A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

B


$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

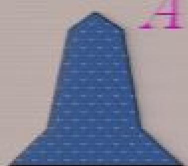
NO MEASUREMENT IN *A* : $P_A = ?$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

NO CHANGE

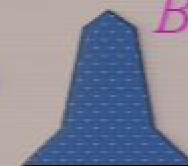
There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ **randomness, action at a distance**



A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A|0\rangle_B + |0\rangle_A|1\rangle_B)$$



B

$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

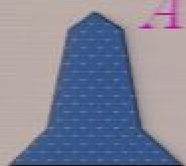
MEASUREMENT IN *A* : $P_A = ?$

$$P_A = 1$$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

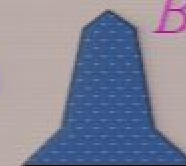
There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ **randomness, action at a distance**



A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



B

$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A*: $\mathrm{P}_A = ?$

no collapse

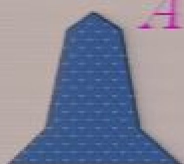
$$\frac{1}{\sqrt{2}}|R\rangle_{MD}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

$$\to \frac{1}{\sqrt{2}}(|1\rangle_{MD} |1\rangle_A |0\rangle_B + |0\rangle_{MD} |0\rangle_A |1\rangle_B)$$

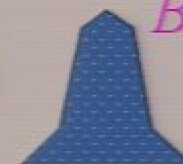
$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

There is no collapse

All is $|\Psi\rangle$ + Collapse $\Rightarrow$ **randomness, action at a distance**



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A*: $\mathrm{P}_A = ?$

no collapse

$$\frac{1}{\sqrt{2}}|R\rangle_{MD}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

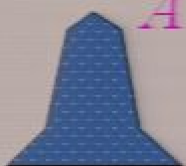
$$\rightarrow \frac{1}{\sqrt{2}}(|1\rangle_{MD} |1\rangle_A |0\rangle_B + |0\rangle_{MD} |0\rangle_A |1\rangle_B)$$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

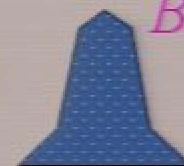
NO CHANGE

There is no collapse

Bell: All ~~is $|\Psi\rangle$~~ + Collapse $\Rightarrow$ randomness



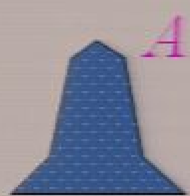
$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



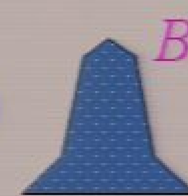
$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

There is no collapse

Bell: ~~All is $|\Psi\rangle$~~ + Collapse $\Rightarrow$ randomness



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A|0\rangle_B + |0\rangle_A|1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $P_A = ?$

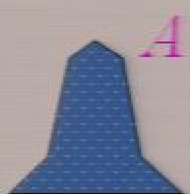
$P_A = 1$

OR **random event**

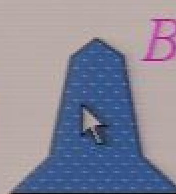
$P_A = 0$ because P_A was not definite before

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $P_A = ?$

$P_A = 1$

OR random event

$P_A = 0$ because P_A was not definite before

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness action at a distance

A B

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

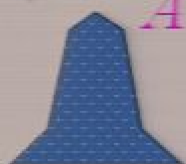
$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

NO MEASUREMENT IN ***A*** : $P_A = ?$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

There is no collapse

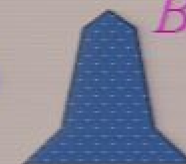
Bell: ~~All is $|\Psi\rangle$~~ + Collapse $\Rightarrow$ randomness



A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

B



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $P_A = ?$

$P_A = 1$

OR **random event**

$P_A = 0$ because P_A was not definite before

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness

A $\qquad$ B

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A|0\rangle_B + |0\rangle_A|1\rangle_B)$$

$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $P_A = ?$

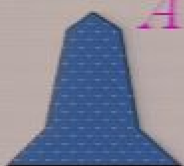
$P_A = 1$

OR $\qquad$ random event

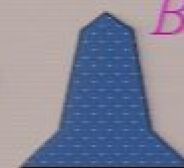
$P_A = 0$ $\qquad$ because P_A was not definite before

Measurements do not have (single) outcomes

Bell: **Measurements have single outcomes** $\Rightarrow$ **randomness action at a distance**


A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$


B

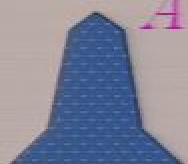
$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

NO MEASUREMENT IN *A*: $P_A = ?$

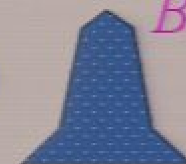
$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness action at a distance

A 

$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|a\rangle + |b\rangle\right) = \frac{1}{\sqrt{2}}\left(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B\right)$$

 B

$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

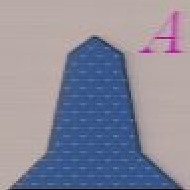
NO MEASUREMENT IN *A*: $\mathrm{P}_A = ?$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

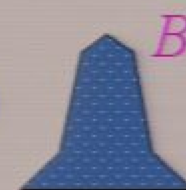
because P_B was not definite before

Measurements do not have (single) outcomes

Bell: | Measurements have single outcomes | $\Rightarrow$ | randomness action at a distance |



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

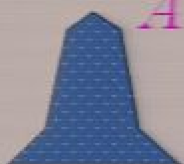
MEASUREMENT IN *A*: $P_A = ?$

$$P_A = 1$$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

Measurements do not have (single) outcomes

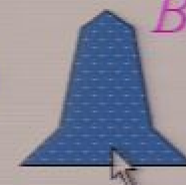
Bell: Measurements have single outcomes $\Rightarrow$ randomness action at a distance



A

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$

B



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

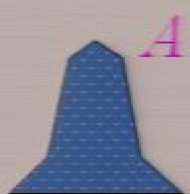
MEASUREMENT IN *A*: $\mathrm{P}_A = ?$

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

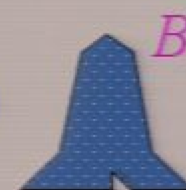
$$\mathrm{P}_A = 0$$

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness action at a distance



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $P_A = ?$

$P_A = 1$

OR

$P_A = 0$

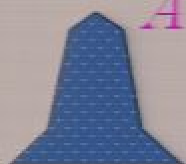
random event

because P_A was not definite before

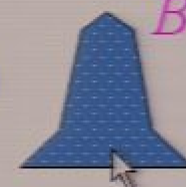
$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} \text{ OR } \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness action at a distance



$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $P_A = ?$

PROPER MIXTURE ?

$$\begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

$P_A = 1$

OR

$P_A = 0$

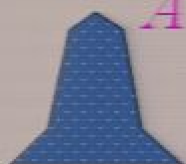
random event

because P_A was not definite before

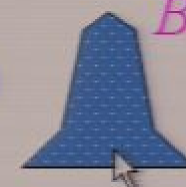
$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} \text{ OR } \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

Measurements do not have (single) outcomes

Bell: Measurements have single outcomes $\Rightarrow$ randomness action at a distance



A $\quad |\Psi\rangle = \frac{1}{\sqrt{2}}(|a\rangle + |b\rangle) = \frac{1}{\sqrt{2}}(|1\rangle_A |0\rangle_B + |0\rangle_A |1\rangle_B)$ $\quad B$



$$\rho_A = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \qquad \rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$$

MEASUREMENT IN *A* : $\mathrm{P}_A = ?$

PROPER MIXTURE ?

$\begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$

$\mathrm{P}_A = 1$

OR

random event

$\mathrm{P}_A = 0$

because P_A was not definite before

$$\rho_B = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} \text{ OR } \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

PROPER MIXTURE DOES NOT EXIST

All is $\Psi(r,t)$

evolving according to relativistic generalization of the Schrodinger equation

NO COLLAPSE!

All is a single Universe

$$\Psi(\vec{r}_1,\vec{r}_2,.....,\vec{r}_N,t)$$

A CENTURY AGO:

All is particles

evolving according to Newton's equations

$$\left(\vec{r}_1(t), \vec{r}_2(t), \ldots, \vec{r}_N(t)\right)$$

Laplacian determinism

Laplacian determinism

Experience $\Longleftrightarrow$ $\left(\vec{r}_1(t), \vec{r}_2(t), \ldots., \vec{r}_N(t)\right)$

The Many Worlds Interpretation

Experience $\Longleftrightarrow$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots., \vec{r}_N, t)$

Laplacian determinism

TRIVIAL

Experience $\Longleftrightarrow$ $\left(\vec{r}_1(t),\vec{r}_2(t),\ldots.,\vec{r}_N(t)\right)$

The Many Worlds Interpretation

CONSISTENT

Experience $\Longleftrightarrow$ $\Psi(\vec{r}_1,\vec{r}_2,\ldots.,\vec{r}_N,t)$

Laplacian determinism

TRIVIAL

Experience $\Longleftrightarrow$ $$\left(\vec{r}_1(t), \vec{r}_2(t), \ldots., \vec{r}_N(t)\right)$$

The Many Worlds Interpretation

CONSISTENT

Experience $\Longleftarrow$ $$\Psi(\vec{r}_1, \vec{r}_2, \ldots., \vec{r}_N, t)$$

Laplacian determinism

Experience $\overset{\text{TRIVIAL}}{\Longleftrightarrow}$ $\left(\vec{r}_1(t), \vec{r}_2(t), \ldots, \vec{r}_N(t)\right)$

The Many Worlds Interpretation

Many Experiences $\overset{\text{CONSISTENT}}{\Longleftrightarrow}$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

The Many Worlds Interpretation

Many Experiences $\Longleftrightarrow$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

The Many Worlds Interpretation

Many Experiences $\Longleftrightarrow$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

many experiences $\Longleftrightarrow$ many worlds $\Longleftrightarrow$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

The Many Worlds Interpretation

Many Experiences $\Leftrightarrow$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

many experiences $\Leftrightarrow$ many worlds $\Leftrightarrow$ $\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

experience i $\Leftrightarrow$ world i $\Leftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

$$\Psi(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t) = \sum \alpha_i \, \Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$$

What is "a world" in the many-worlds picture?

experience i $\Leftrightarrow$ world i $\Leftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

What is "a world" in the many-worlds picture?

experience i $\Leftrightarrow$ world i $\Leftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

An observer has definite experience.

Everett's Relative State World

What is "a world" in the many-worlds picture?

experience i $\Leftrightarrow$ world i $\Leftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

An observer has definite experience.

Everett's Relative State World

$$\Psi_i = \psi_i^{OBSERVER} \; \varphi_i^{REST}$$

What is "a world" in the many-worlds picture?

experience i $\Longleftrightarrow$ world i $\Longleftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \dots, \vec{r}_N, t)$

An observer has definite experience.

Everett's Relative State World

$$\Psi_i = \psi_i^{OBSERVER} \; \varphi_i^{REST}$$

A world is the totality of (macroscopic) objects: stars, cities, people, grains of sand, etc. in a definite classically described state.

The MWI in SEP

What is "a world" in the many-worlds picture?

experience i $\Longleftrightarrow$ world i $\Longleftrightarrow$ $\Psi_i(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t)$

An observer has definite experience.

Everett's Relative State World

$$\Psi_i = \psi_i^{OBSERVER} \ \varphi_i^{REST}$$

A world is the totality of (macroscopic) objects: stars, cities, people, grains of sand, etc. in a definite classically described state.

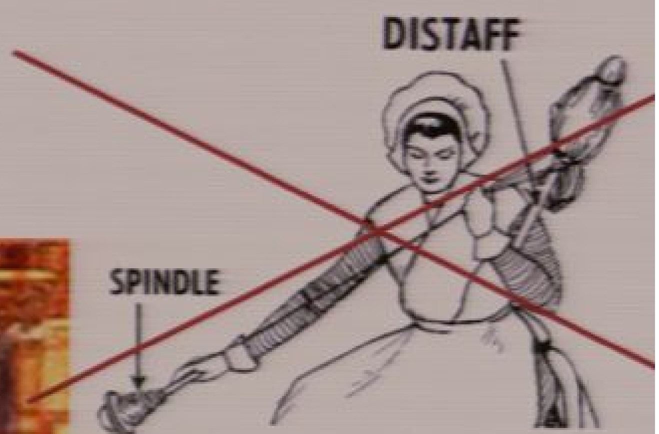
The MWI in SEP

$$\Psi_i = \psi_i^{OBJECT_1} \ \psi_i^{OBJECT_2} \ldots \psi_i^{OBJECT_K} \varphi_i^{REST}$$

ψ_i^{OBJECT} is a Localized Wave Packet for a period of time

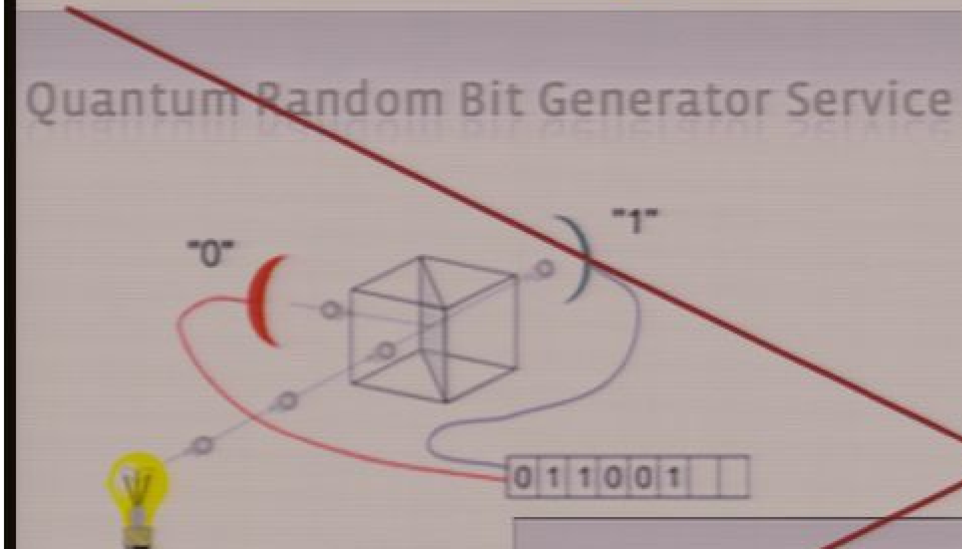
A tale of a single world universe

The king forbade spinning on distaff or spindle, or the possession of one, upon pain of death, throughout the kingdom

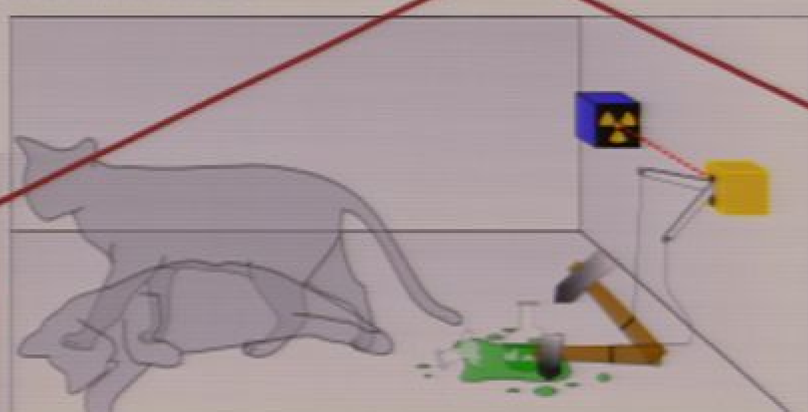


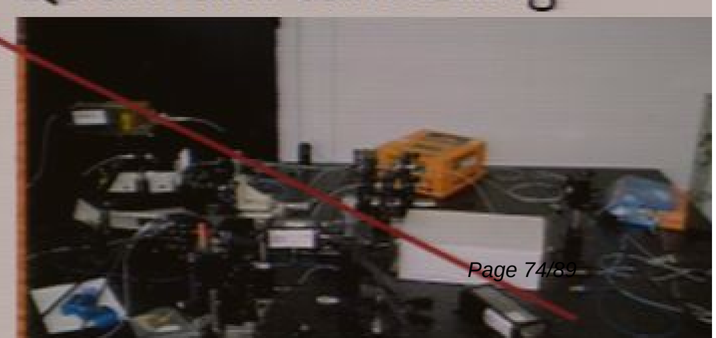
A tale of a single world universe

The king forbade performing quantum measurements, or the possession of quantum devices, upon pain of death, throughout the kingdom



- Photomultipliers
- Geiger counters
- Stern Gerlach devices
- Beam splitters
- Down conversion crystals
- Quantum dots
- Quantum tunneling





A tale of a single world universe

$$\Psi^{UNIVERSE} = \Psi^{WORLD} = \psi^{OBJECT_1}\,\psi^{OBJECT_2}\ldots\psi^{OBJECT_K}\varphi^{REST}$$

A tale of a single world universe

$$\Psi^{UNIVERSE} = \Psi^{WORLD} = \psi^{OBJECT_1}\,\psi^{OBJECT_2}\ldots\psi^{OBJECT_K}\varphi^{REST}$$

Quantum states of all macroscopic objects are Localized Wave Packets all the time

A tale of a single world universe

$$\Psi^{UNIVERSE} = \Psi^{WORLD} = \psi^{OBJECT_1}\,\psi^{OBJECT_2}\ldots\psi^{OBJECT_K}\,\varphi^{REST}$$

Quantum states of all macroscopic objects are Localized Wave Packets all the time

Zero approximation: all particles remain in product LWP states $\psi^n(\vec{r}_n)$

$$\Psi^{WORLD}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t) = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

A tale of a single world universe

$$\Psi^{UNIVERSE} = \Psi^{WORLD} = \psi^{OBJECT_1}\,\psi^{OBJECT_2}\ldots\psi^{OBJECT_K}\varphi^{REST}$$

Quantum states of all macroscopic objects are Localized Wave Packets all the time

Zero approximation: all particles remain in product LWP states $\psi^{n}(\vec{r}_n)$

$$\Psi^{WORLD}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t) = \psi^{1}(\vec{r}_1)\,\psi^{2}(\vec{r}_2)\ldots\psi^{N}(\vec{r}_N)$$

Particles which do not interact strongly with "macroscopic objects" need not be in LWP states.

$$\Psi^{WORLD} = \psi^{1}(\vec{r}_1)\,\psi^{2}(\vec{r}_2)\ldots\psi^{K}(\vec{r}_K)\,\Phi^{REST}$$

A tale of a single world universe

$$\Psi^{UNIVERSE} = \Psi^{WORLD} = \psi^{OBJECT_1}\,\psi^{OBJECT_2}\ldots\psi^{OBJECT_K}\varphi^{REST}$$

Quantum states of all macroscopic objects are Localized Wave Packets all the time

Zero approximation: all particles remain in product LWP states $\psi^n(\vec{r}_n)$

$$\Psi^{WORLD}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t) = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

Particles which do not interact strongly with "macroscopic objects" need not be in LWP states.

$$\Psi^{WORLD} = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^K(\vec{r}_K)\,\Phi^{REST}$$

Particles which make atoms, molecules, etc. can (and should be) entangled among themselves. Only states of the center of mass of molecules, cat's nails etc. have to be in LWP states.

$$\Psi^{WORLD} = \psi^1_{CM}(\vec{r}^{\,CM}_1)\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}^{\,CM}_2)\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}^{\,CM}_M)\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

A tale of a single world universe

Quantum states of all macroscopic objects are
Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}^{\,CM}_1)\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}^{\,CM}_2)\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}^{\,CM}_M)\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

A tale of a single world universe

Quantum states of all macroscopic objects are Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t) = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD} = \psi^1_{CM}(\vec{r}^{\,CM}_1)\,\varphi^1_{rel}(\vec{r}_{1i} - \vec{r}_{1j})\,\psi^2_{CM}(\vec{r}^{\,CM}_2)\,\varphi^2_{rel}(\vec{r}_{2i} - \vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}^{\,CM}_M)\,\varphi^1_{rel}(\vec{r}_{Mi} - \vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \rho(\vec{r})$ $\rho(\vec{r})$ **of a cat!**

A tale of a single world universe

Quantum states of all macroscopic objects are

Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t) = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD} = \psi^1_{CM}(\vec{r}_1^{\,CM})\,\varphi^1_{rel}(\vec{r}_{1i} - \vec{r}_{1j})\,\psi^2_{CM}(\vec{r}_2^{\,CM})\,\varphi^2_{rel}(\vec{r}_{2i} - \vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}_M^{\,CM})\,\varphi^1_{rel}(\vec{r}_{Mi} - \vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \quad \rho(\vec{r})$ $\qquad$ $\rho(\vec{r})$ **of a cat!**

A tale of a single world universe

Quantum states of all macroscopic objects are Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t) = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD} = \psi^1_{CM}(\vec{r}^{\,CM}_1)\,\varphi^1_{rel}(\vec{r}_{1i} - \vec{r}_{1j})\,\psi^2_{CM}(\vec{r}^{\,CM}_2)\,\varphi^2_{rel}(\vec{r}_{2i} - \vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}^{\,CM}_M)\,\varphi^1_{rel}(\vec{r}_{Mi} - \vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \quad \rho(\vec{r})$ $\qquad$ $\rho(\vec{r})$ **of a cat!**

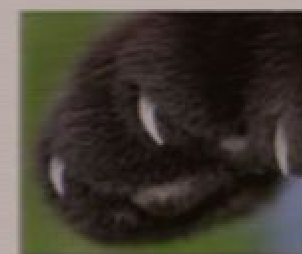
A tale of a single world universe

Quantum states of all macroscopic objects are
Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1, \vec{r}_2, \ldots, \vec{r}_N, t) = \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD} = \psi^1_{CM}(\vec{r}_1^{\,CM})\,\varphi^1_{rel}(\vec{r}_{1i} - \vec{r}_{1j})\,\psi^2_{CM}(\vec{r}_2^{\,CM})\,\varphi^2_{rel}(\vec{r}_{2i} - \vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}_M^{\,CM})\,\varphi^1_{rel}(\vec{r}_{Mi} - \vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \quad \rho(\vec{r})$ $\qquad$ **$\rho(\vec{r})$ of a cat!**



experience $\quad \Leftrightarrow \quad \psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$

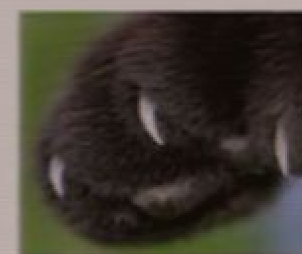
A tale of a single world universe

Quantum states of all macroscopic objects are Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}^{\,CM}_1)\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}^{\,CM}_2)\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}^{\,CM}_M)\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \quad \rho(\vec{r})$ $\qquad$ $\rho(\vec{r})$ **of a cat!**

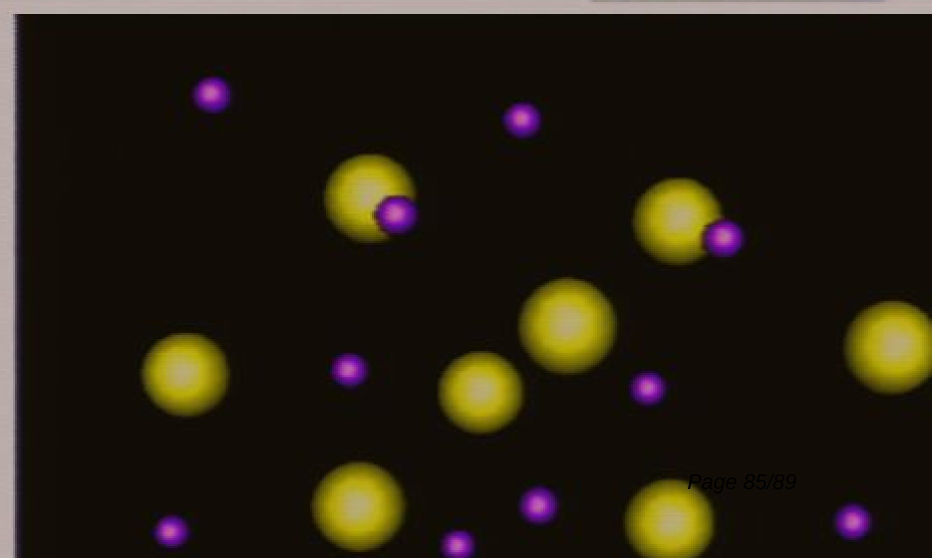


TRIVIAL

experience $\Longleftrightarrow$ $\psi^1(\vec{r}_1)\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$

Almost the same as in

Textbook collapse



A tale of a single world universe

Quantum states of all macroscopic objects are Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}_1^{\,CM})\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\psi^2_{CM}(\vec{r}_2^{\,CM})\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}_M^{\,CM})\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\Phi^{REST}$$

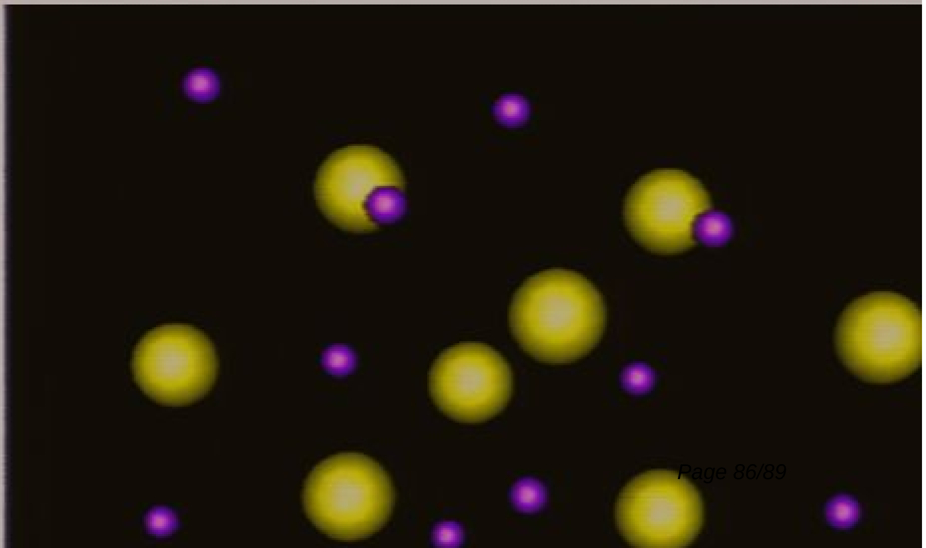
$\Rightarrow\ \rho(\vec{r})$ $\rho(\vec{r})$ **of a cat!**

experience $\overset{\text{TRIVIAL}}{\Longleftrightarrow}$ $\psi^1(\vec{r}_1)\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$

Almost the same as in

Textbook collapse

GRW-Pearle Collapse (mass density)



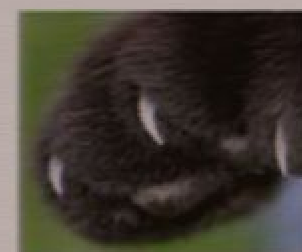
A tale of a single world universe

Quantum states of all macroscopic objects are Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\dots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\dots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}_1^{\,CM})\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}_2^{\,CM})\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\dots\psi^M_{CM}(\vec{r}_M^{\,CM})\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \quad \rho(\vec{r})$ $\qquad\qquad$ $\rho(\vec{r})$ **of a cat!**



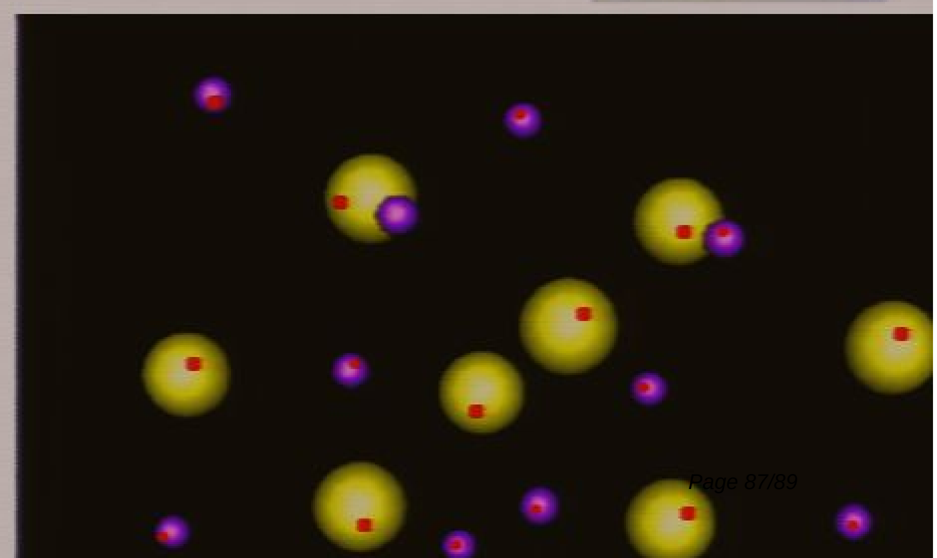
experience $\overset{\text{TRIVIAL}}{\Longleftrightarrow}$ $\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\dots\psi^N(\vec{r}_N)$

Almost the same as in

Textbook collapse

GRW-Pearle Collapse (mass density)

Bohmian trajectories



A tale of a single world universe

Quantum states of all macroscopic objects are Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\dots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\dots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}_1^{\,CM})\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}_2^{\,CM})\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\dots\psi^M_{CM}(\vec{r}_M^{\,CM})\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow\ \rho(\vec{r})$ **$\rho(\vec{r})$ of a cat!**

experience $\overset{\text{TRIVIAL}}{\Longleftrightarrow}$ $\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\dots\psi^N(\vec{r}_N)$

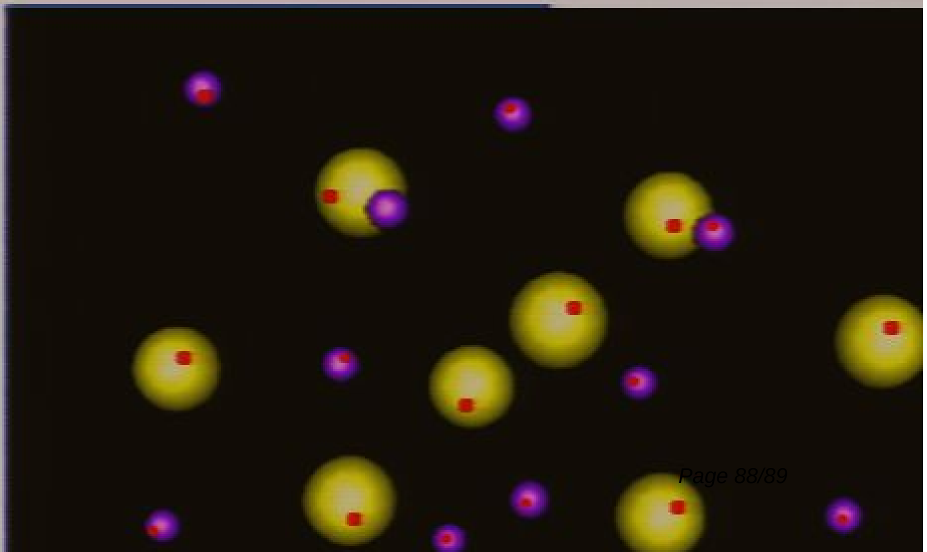
Almost the same as in

Textbook collapse

GRW-Pearle Collapse (mass density)

Bohmian trajectories

Laplacian Determinism



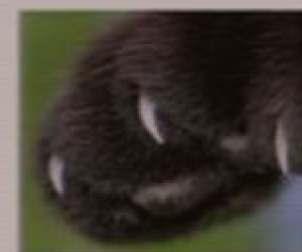
A tale of a single world universe

Quantum states of all macroscopic objects are
Localized Wave Packets all the time

$$\Psi^{UNIVERSE}(\vec{r}_1,\vec{r}_2,\ldots,\vec{r}_N,t)=\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$$

$$\Psi^{WORLD}=\psi^1_{CM}(\vec{r}_1^{\,CM})\,\varphi^1_{rel}(\vec{r}_{1i}-\vec{r}_{1j})\,\psi^2_{CM}(\vec{r}_2^{\,CM})\,\varphi^2_{rel}(\vec{r}_{2i}-\vec{r}_{2j})\ldots\psi^M_{CM}(\vec{r}_M^{\,CM})\,\varphi^1_{rel}(\vec{r}_{Mi}-\vec{r}_{Mj})\,\Phi^{REST}$$

$\Rightarrow \;\rho(\vec{r})$ **$\rho(\vec{r})$ of a cat!**



experience $\overset{\text{TRIVIAL}}{\Longleftrightarrow}$ $\psi^1(\vec{r}_1)\,\psi^2(\vec{r}_2)\ldots\psi^N(\vec{r}_N)$

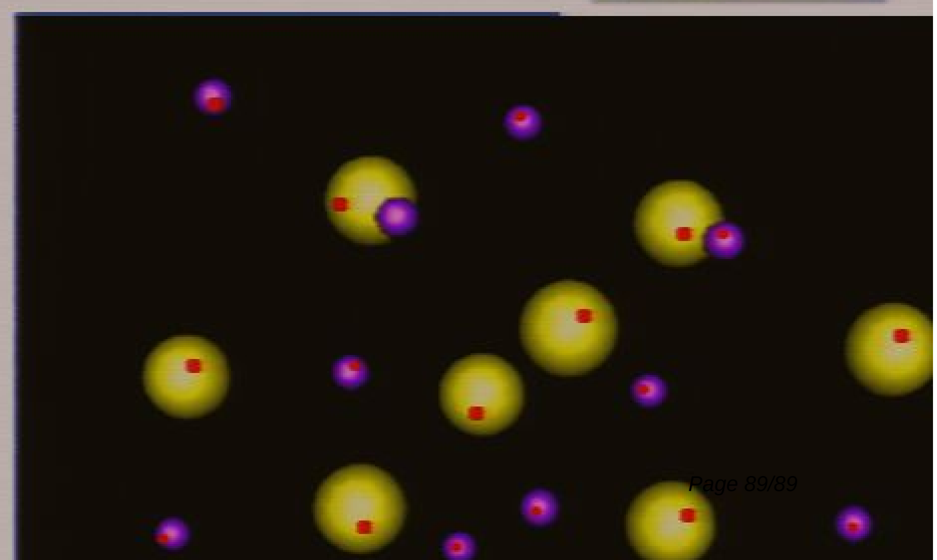
Almost the same as in

Textbook collapse

GRW-Pearle Collapse (mass density)

Bohmian trajectories

Laplacian Determinism



Compare with "QM as probability theory"