

Title: Dynamic Time: The "Missing Link" in the Search for a Unified Theory?

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Abstract: While modern theories lavishly invoke several spatial dimensions within models that seek to unify relativity theory and quantum mechanics, none seems to consider the possibility that a yet-unfamiliar aspect of time may do the work. I introduce the notion of Becoming and then consider its consequences for physical theory. Becoming portrays a possible aspect of time that is "curled" very much like the extra spatial dimensions in superstring theories. Within the resulting picture of spacetime, some fundamental aspects of quantum mechanics, special and general relativity, thermodynamics and modern cosmology fit in very naturally. The proposed model is not yet a scientific theory as it still lacks a rigorous formalism and experimental predictions, yet it points out an entire family of possible theories that merit serious consideration.

# Spacetime Dynamics as a Possible Link between Quantum Mechanics and Relativity

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Bar-Ilan University  
and  
Shahar Dolev  
Hebrew University

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  - Clues for Field Theories



# Time: The Common View

## Events Become and Go, One by One

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# Time: The Relativistic View

## All Events Coexist along Time



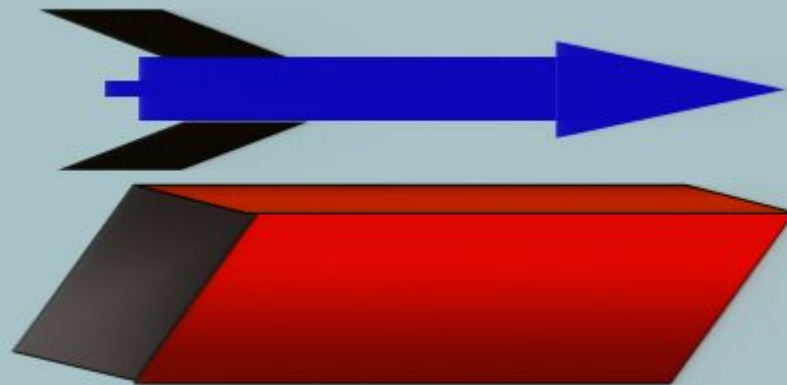


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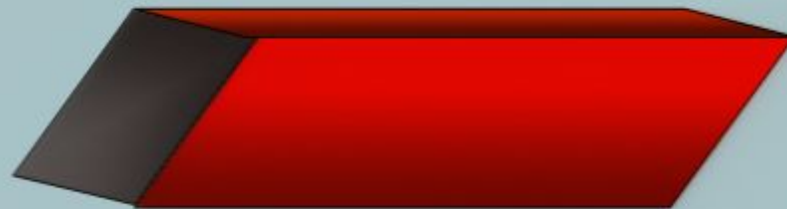
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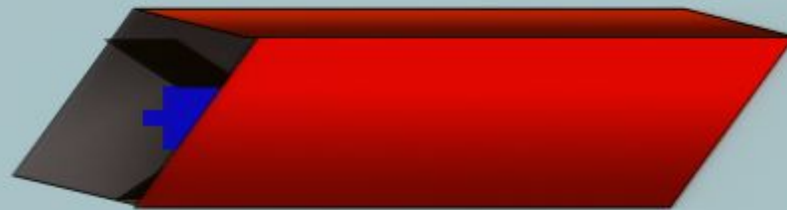
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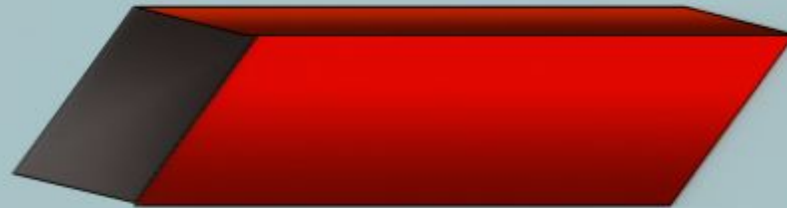


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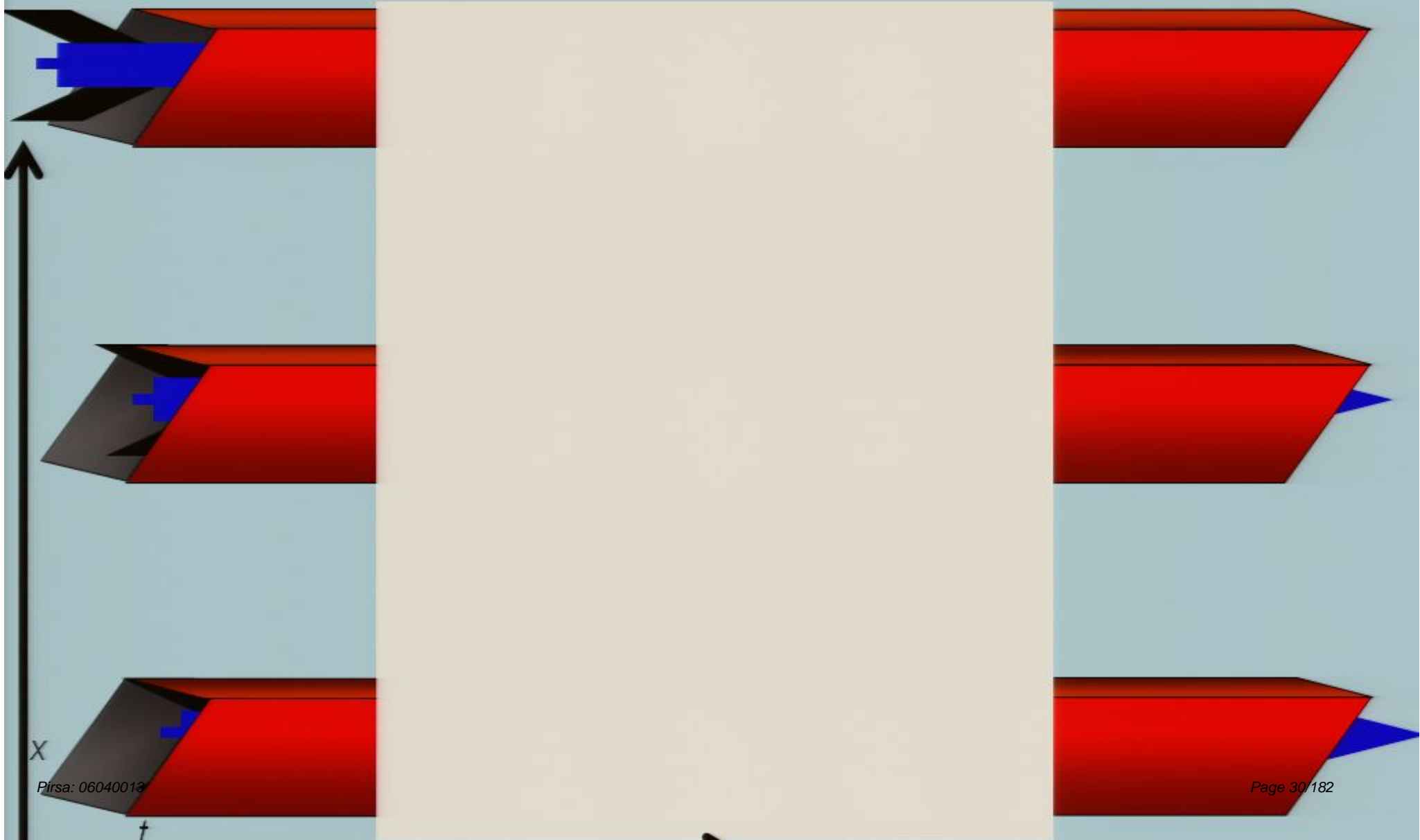




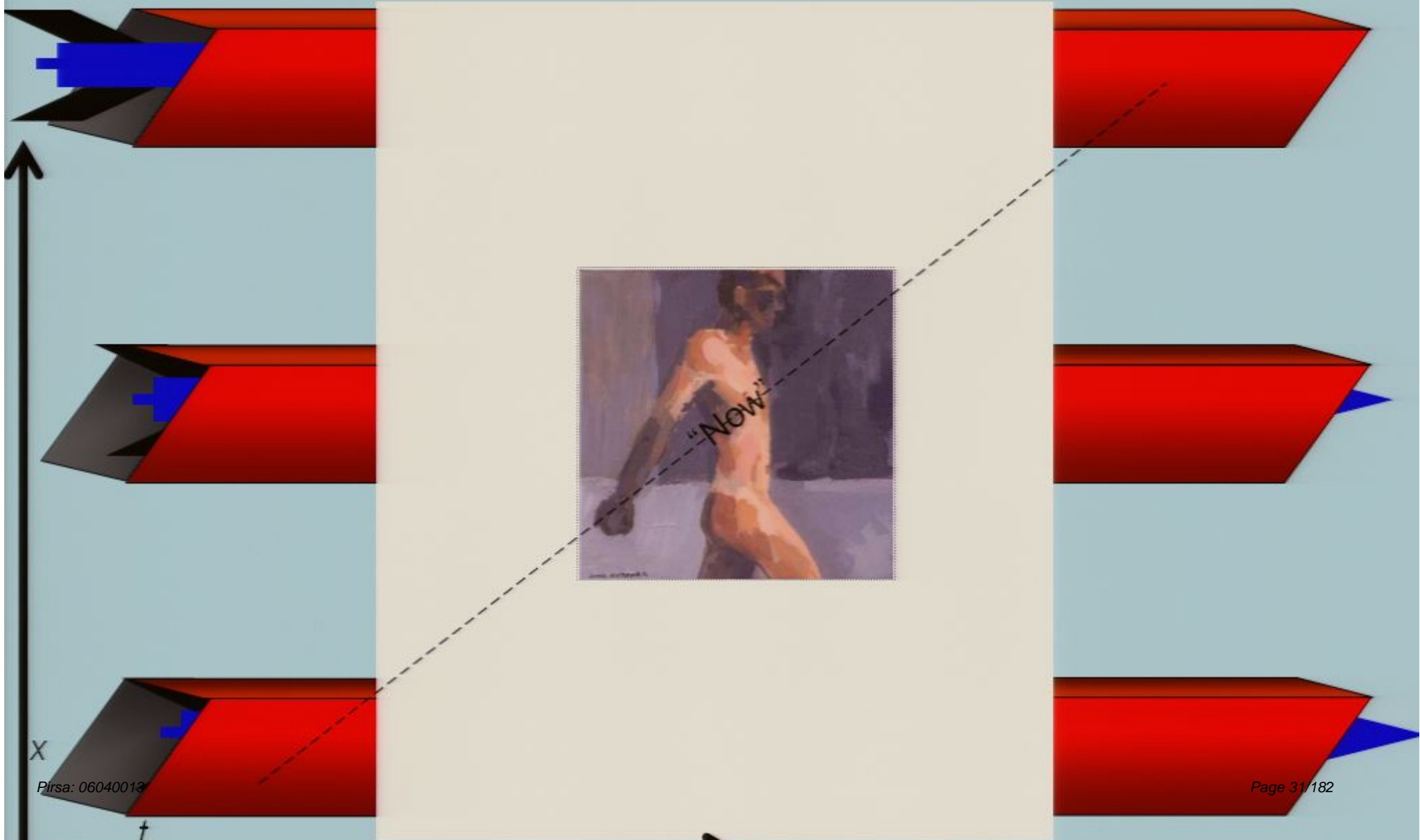
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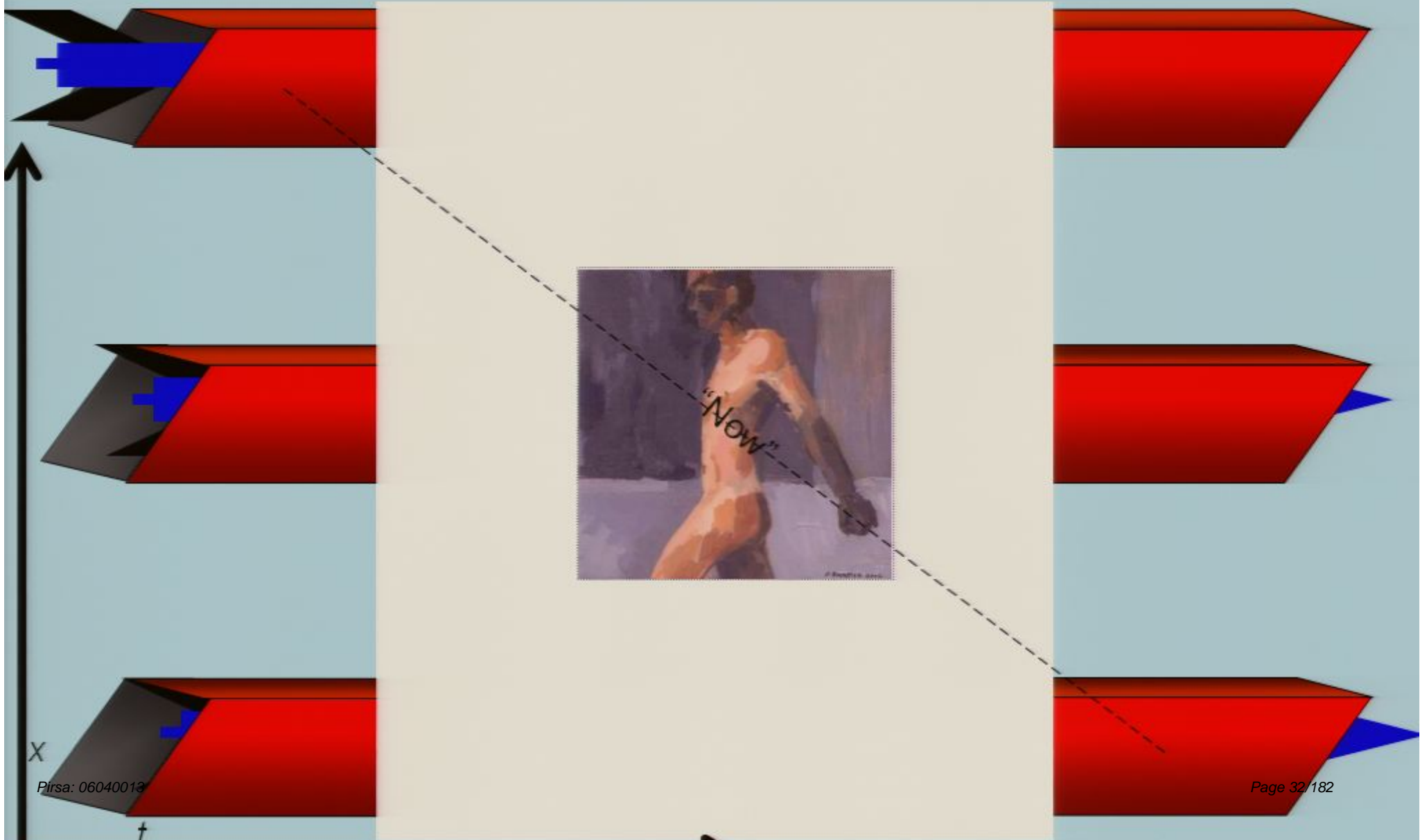
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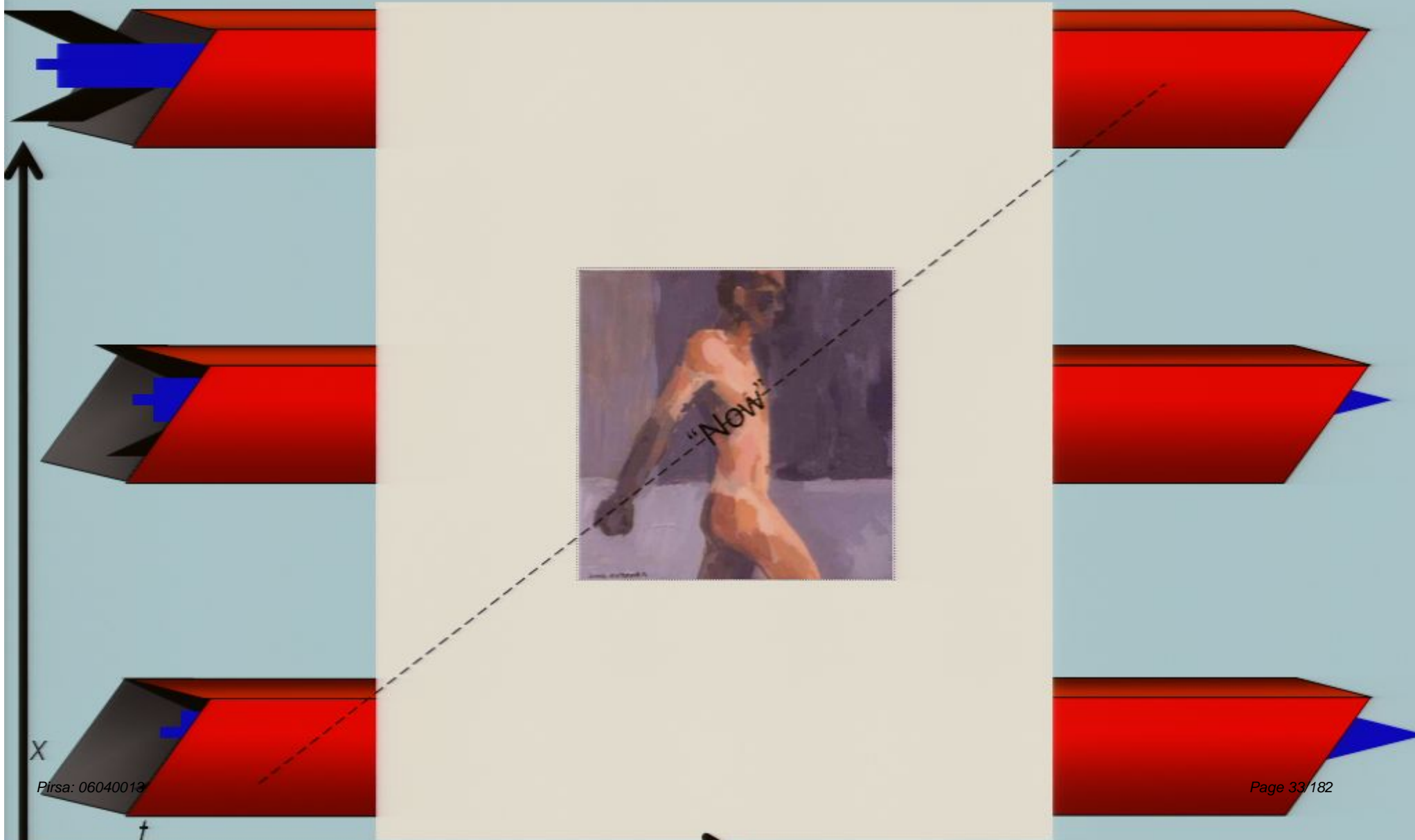
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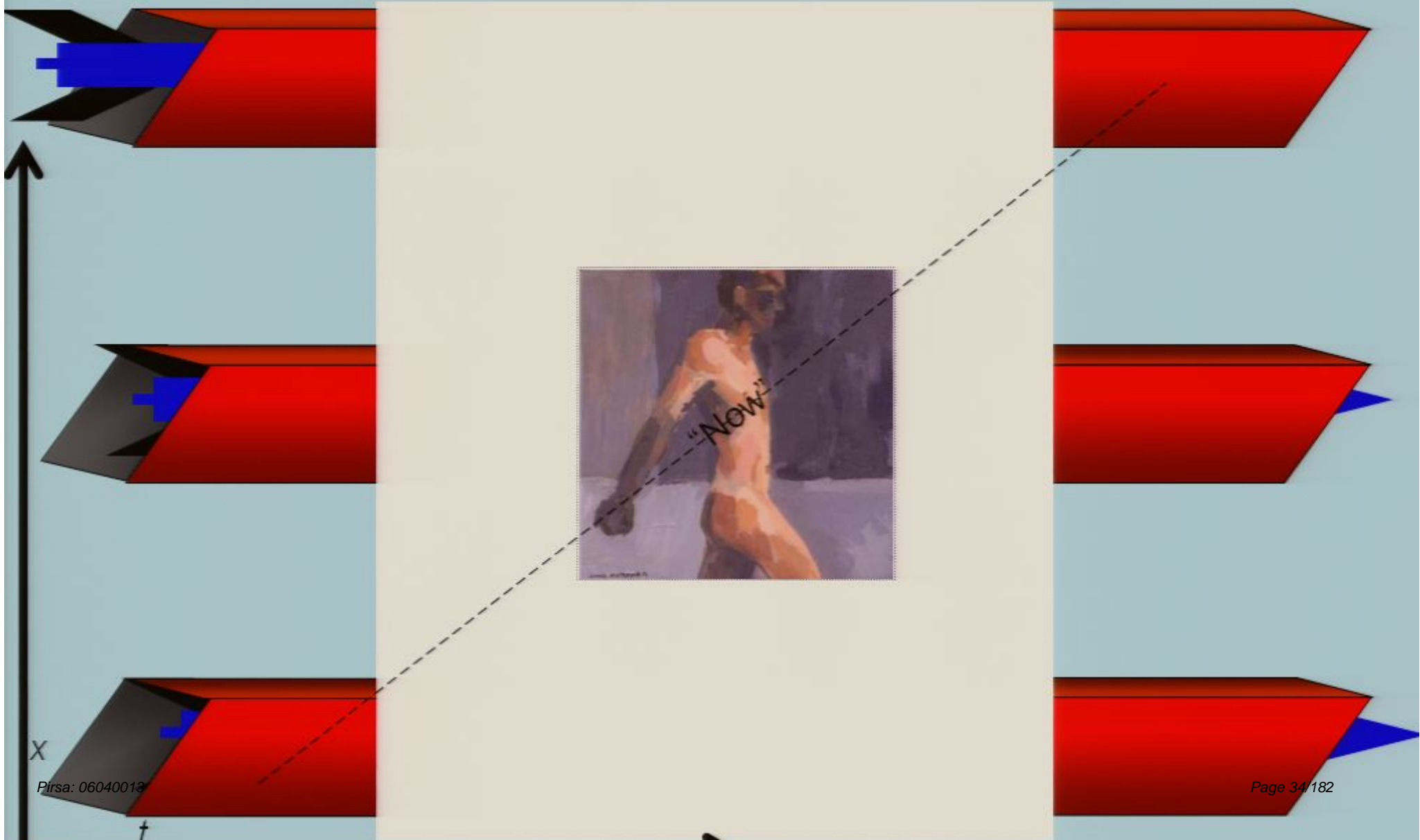


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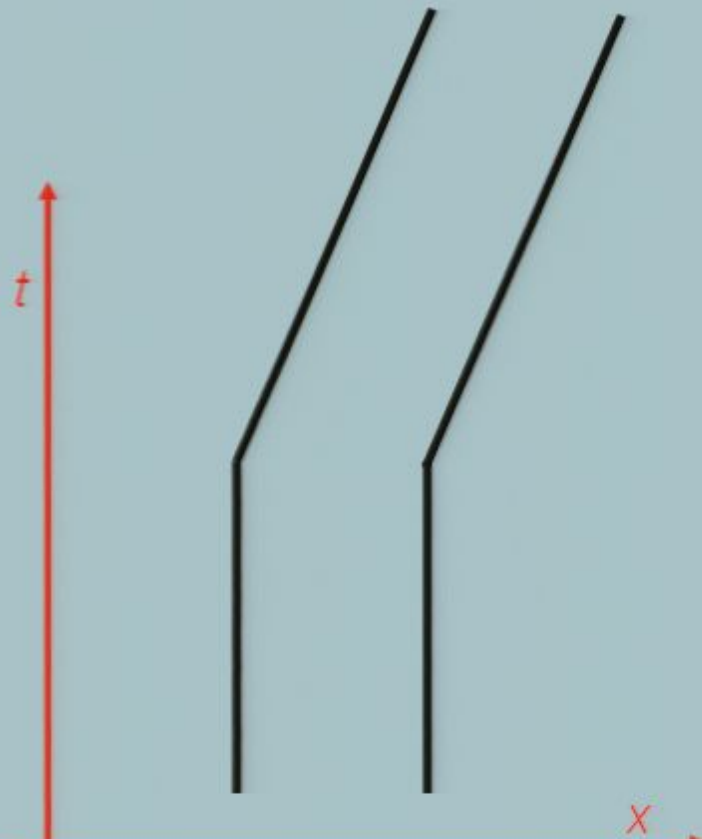




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# Bell's Two Spaceships Paradox: Change of Frame brings about Intriguing Effects



# An Alternative to Block Universe: Presentism

“Only present events are real. The idea of four dimensions and notions such as ‘spacetime’ and ‘world line’ are mere metaphors.”



# The Cure is Worse than the Disease

It is highly unlikely that all the relativistic relations are mere coincidences

Spacetime is a physical entity, interacting with mass and giving rise to curvatures, singularities, etc.

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2. It seems to entail absolute simultaneity

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# Lavishness:

- Extra spatial dimensions
- Hyperspaces
- Multiverse
- Etc.

***All within the Block Universe!***

# Three Prohibitions – Related?

Relativistic locality

Quantum uncertainty

Thermodynamic directionality

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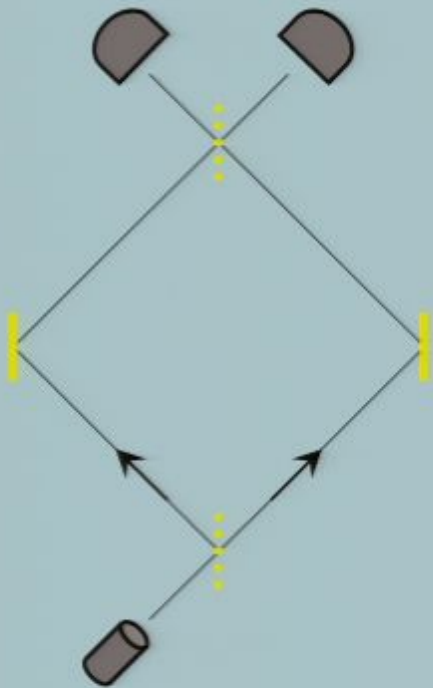
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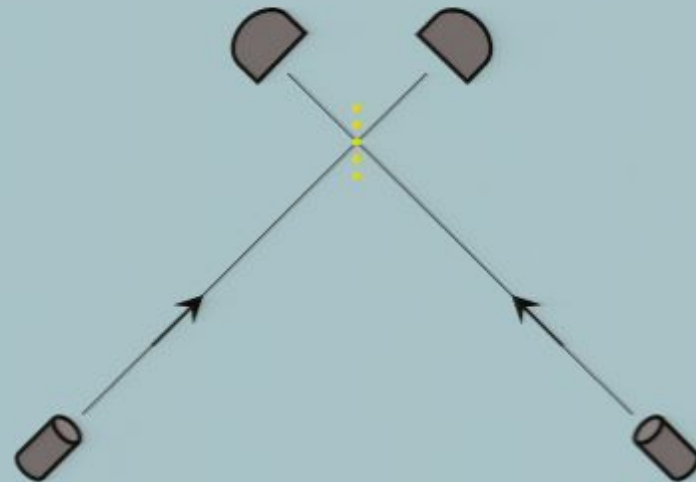
Non-locality would give rise to second-law violations

$$\Delta X \Delta P - \hbar/2 = n \text{ superluminal bits} = K(\ln W_1 - \ln W_2)$$

# Quantum Temporal Peculiarities



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Delayed Choice



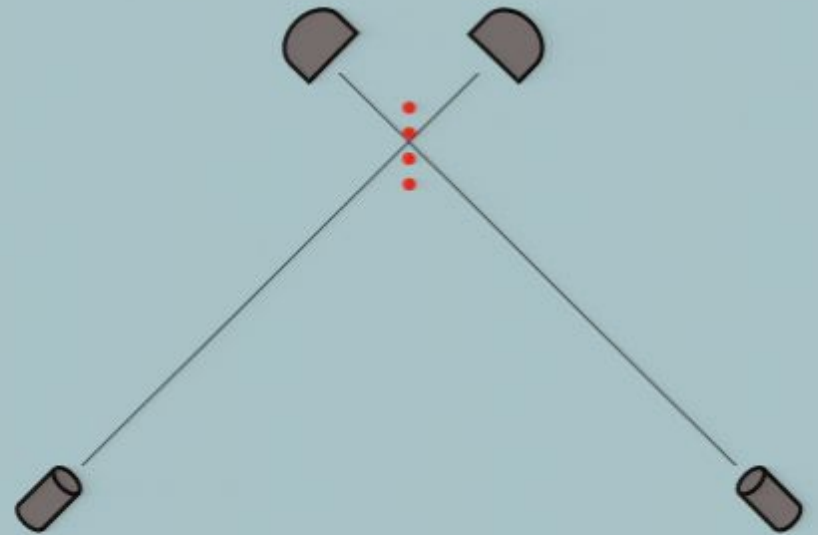
HBT Experiment



Schrödinger's cat

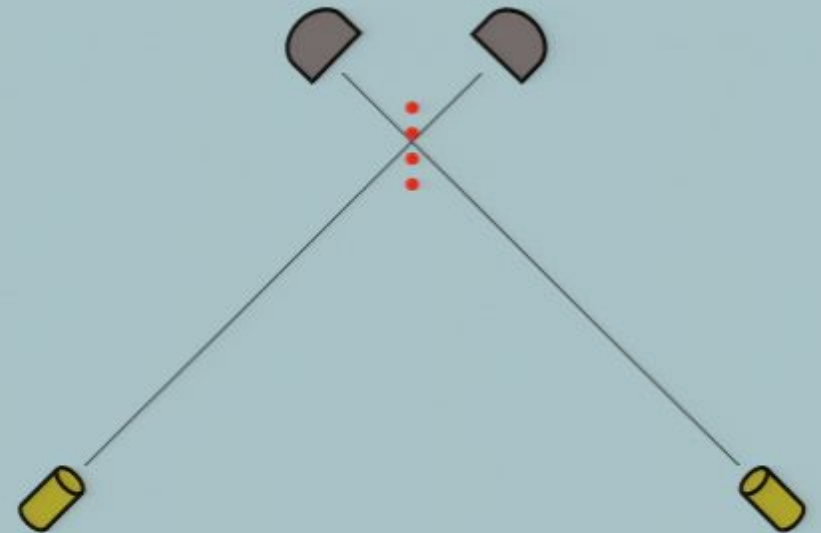
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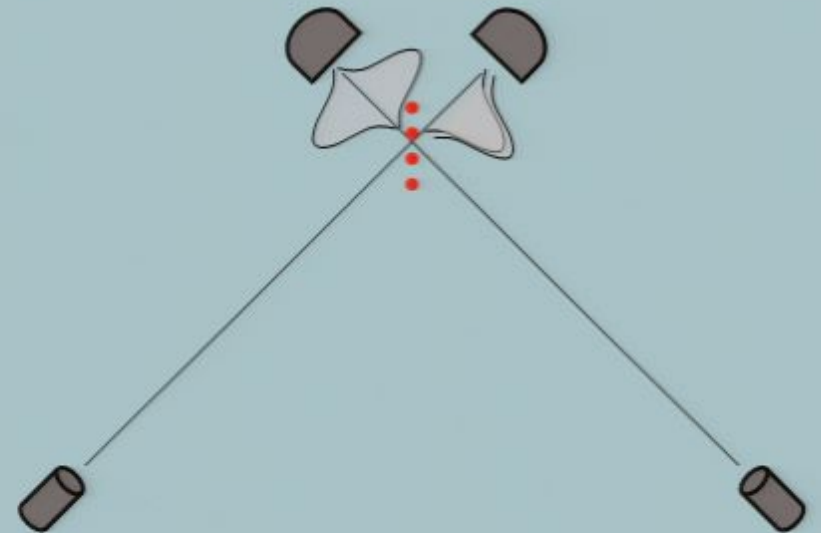
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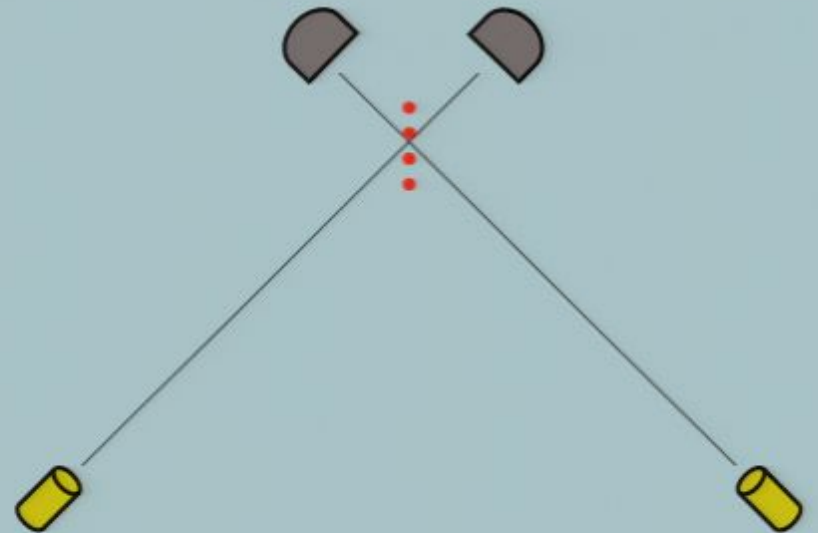
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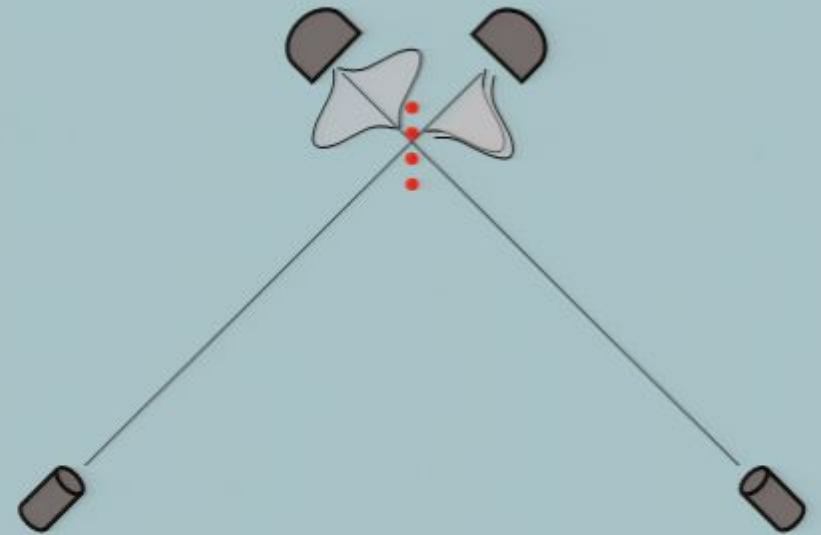
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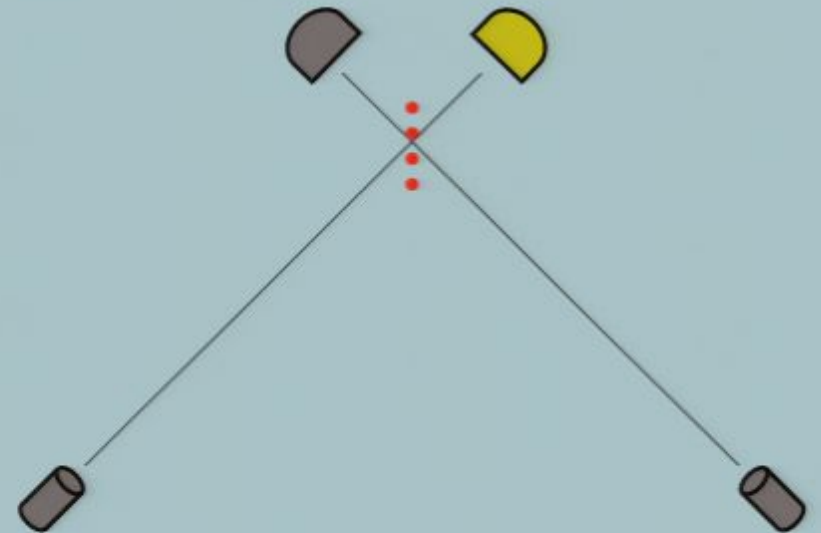
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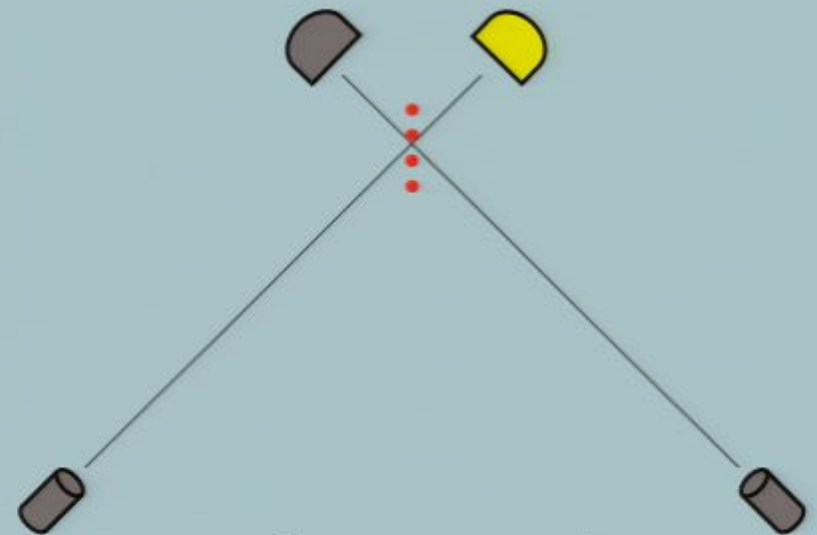
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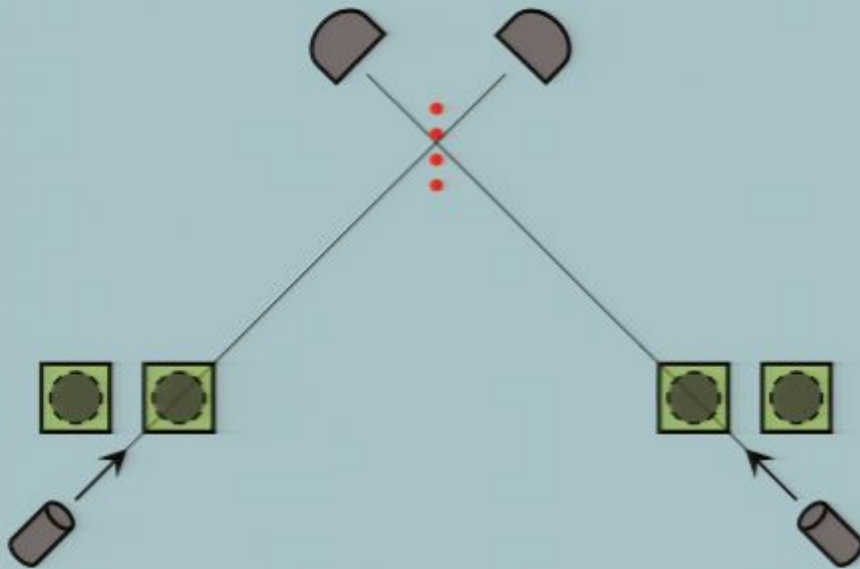
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- Even when the sources are so weak to produce a single photon at a time!

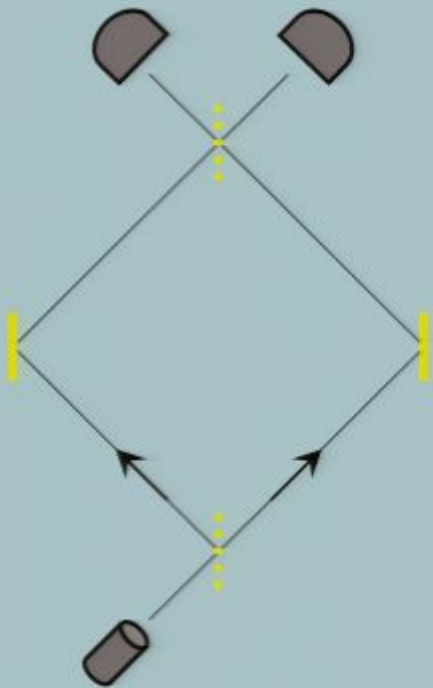
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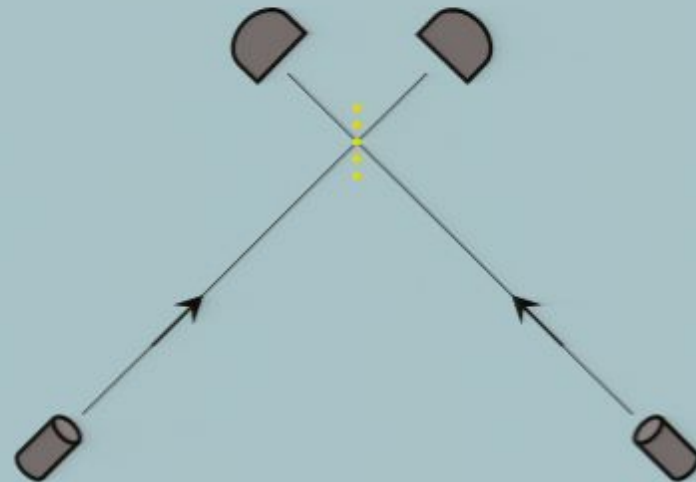




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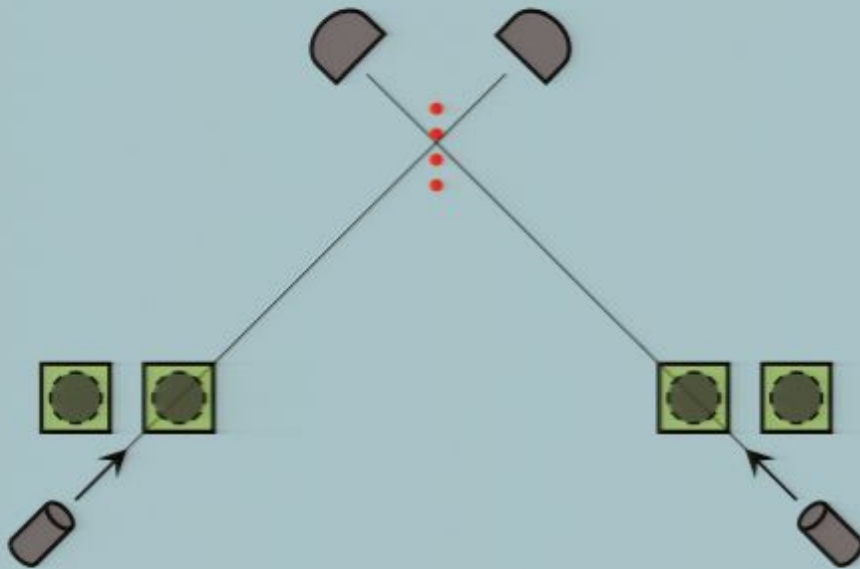
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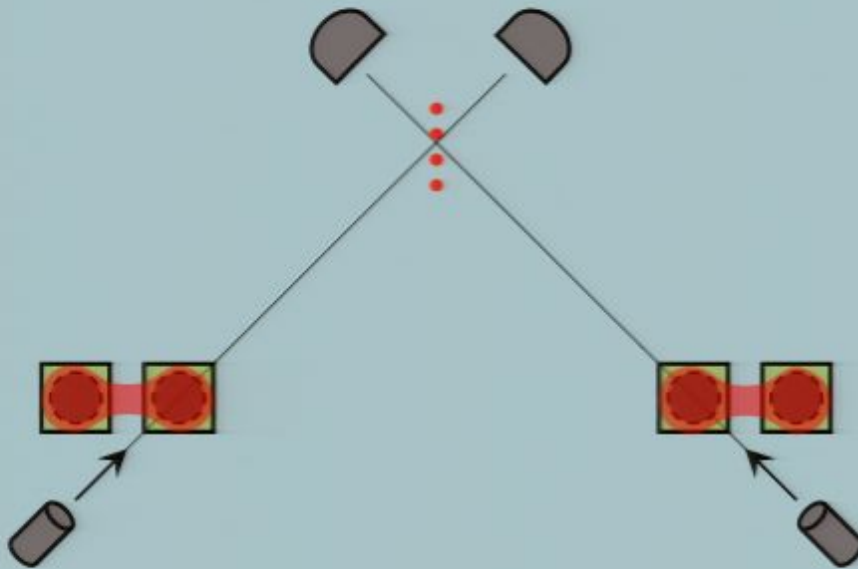
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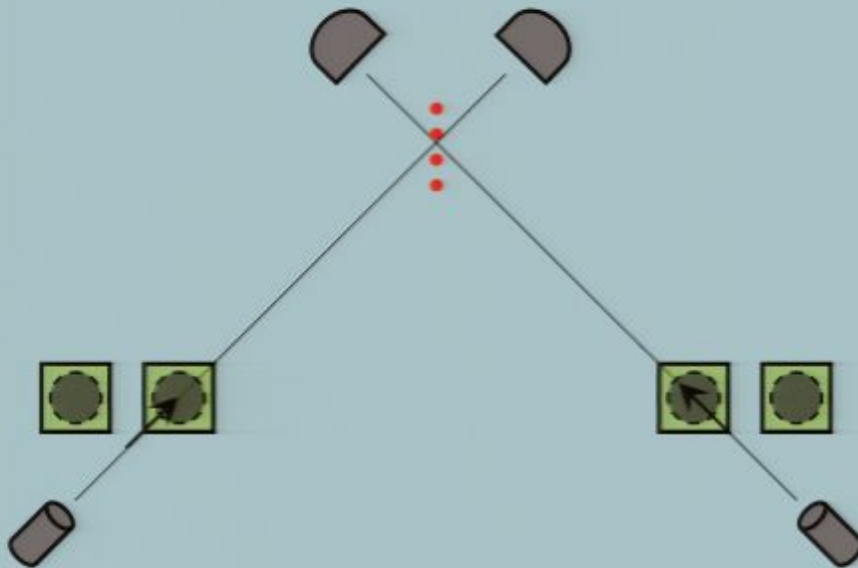


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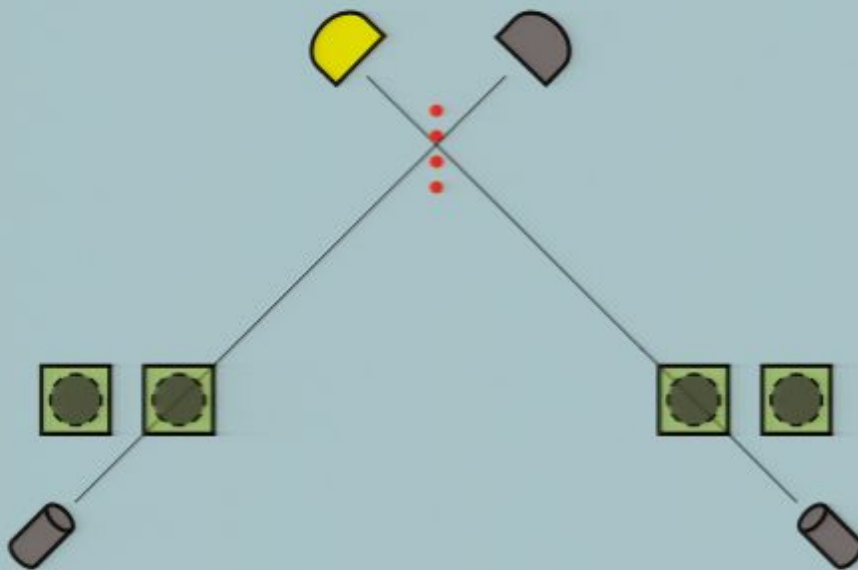


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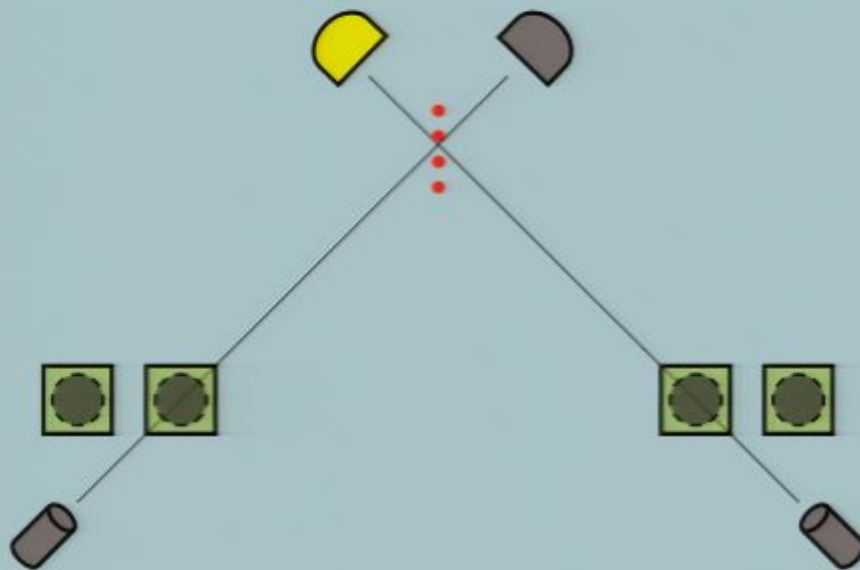
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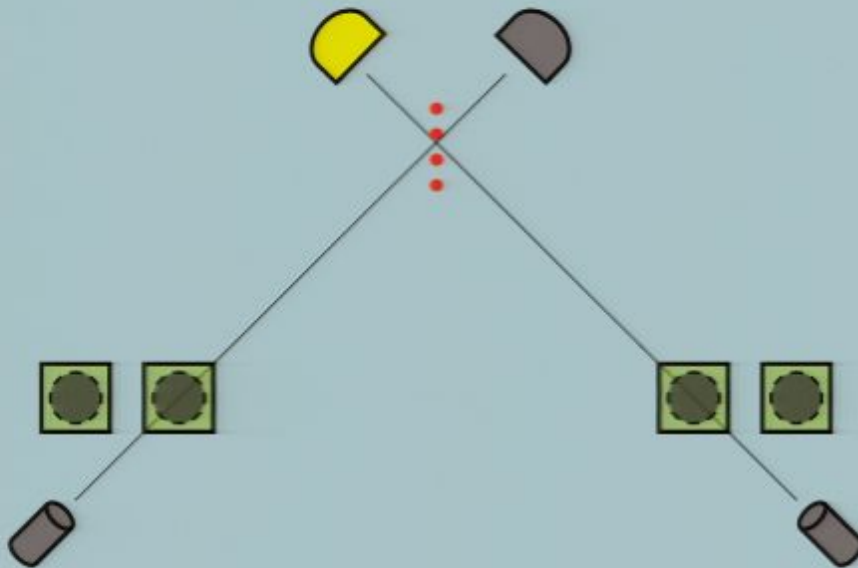
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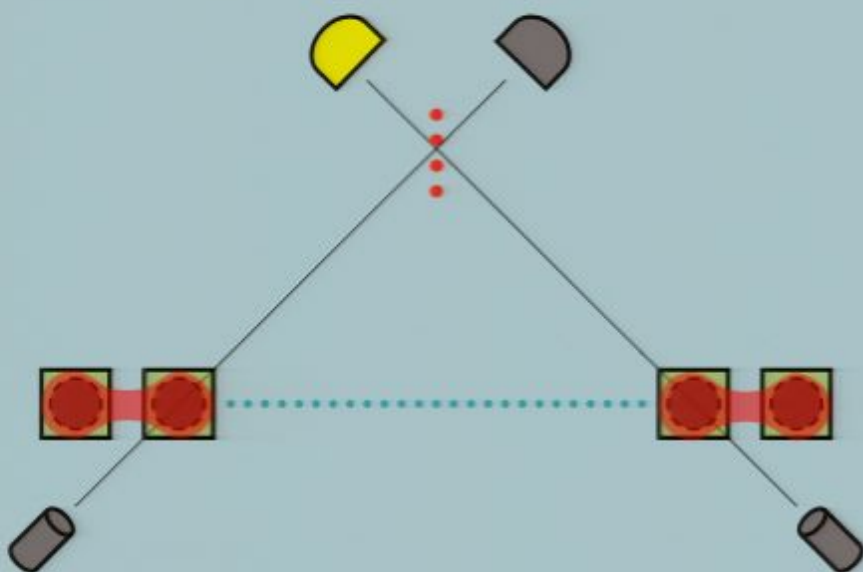


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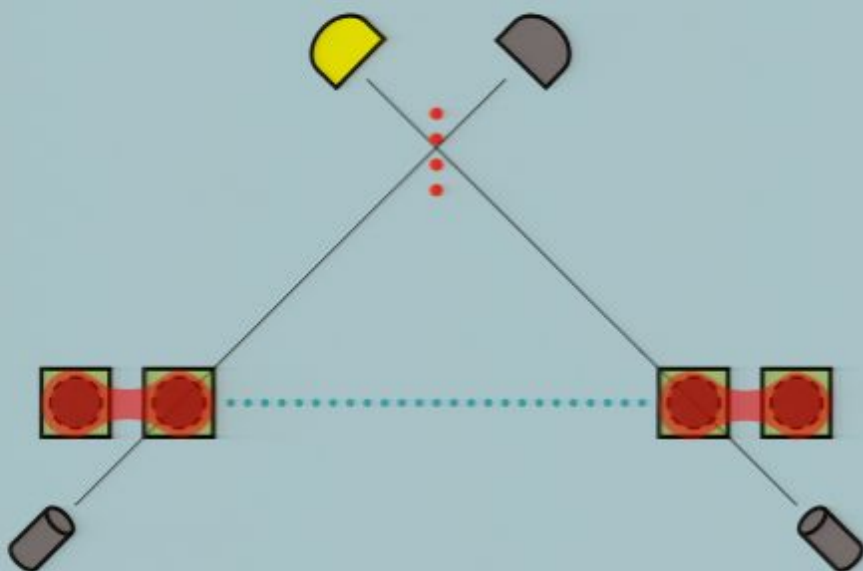


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... or better call it: **RPE**

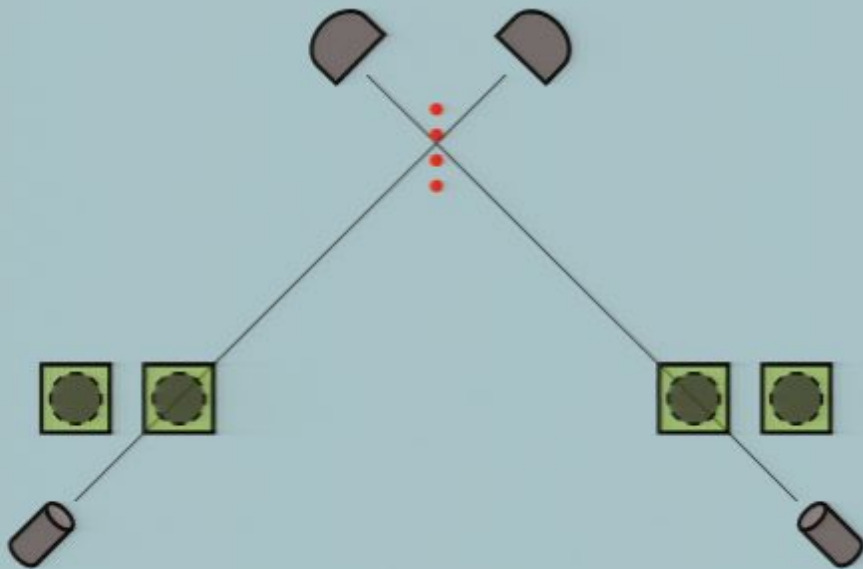
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## Earlier versions

C. Cabillo, J. I. Cirac, P. Garcia-Fernandez, and P. Zoller, *Phys. Rev. A* **59**, 1025 (1999), quant-ph/9810013.

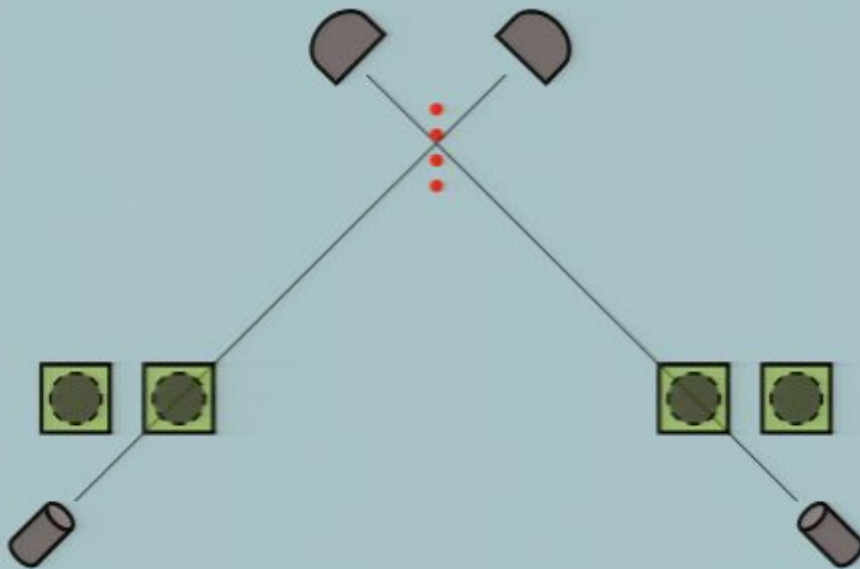
E. Biham, B. Huttner, & T. Mor, *Phys. Rev. A* **54**, 2651–2658 (1996)

# The Quantum Liar Paradox





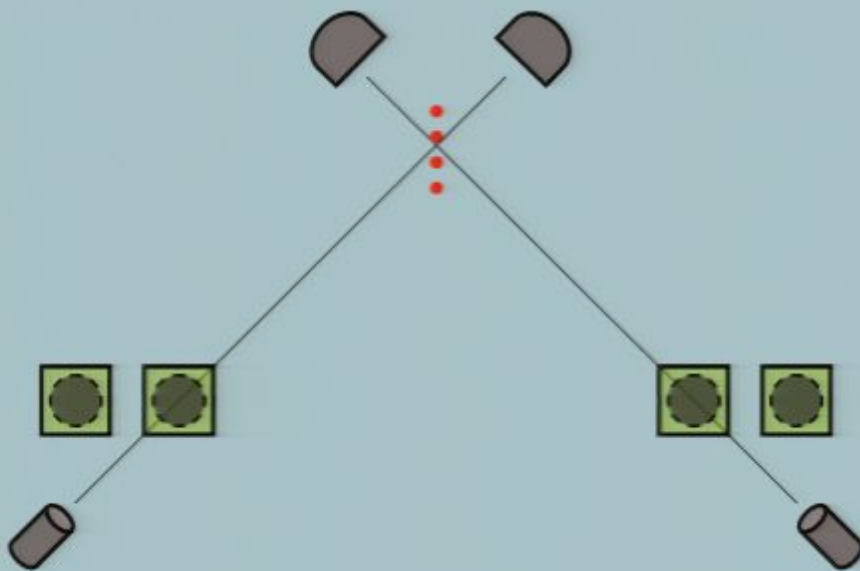
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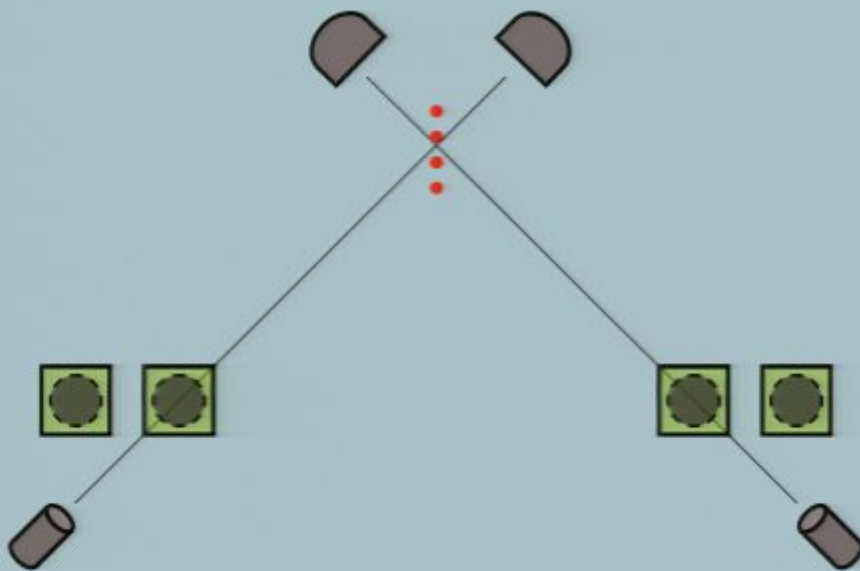


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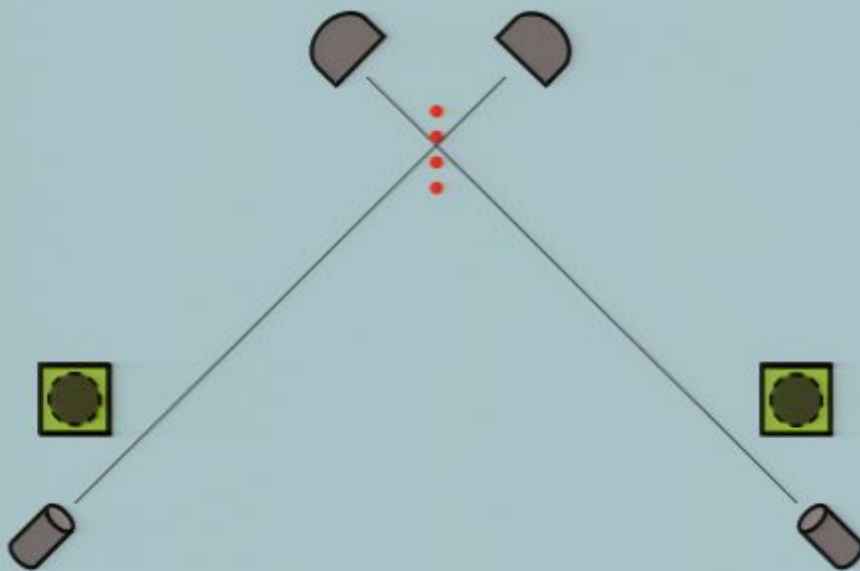
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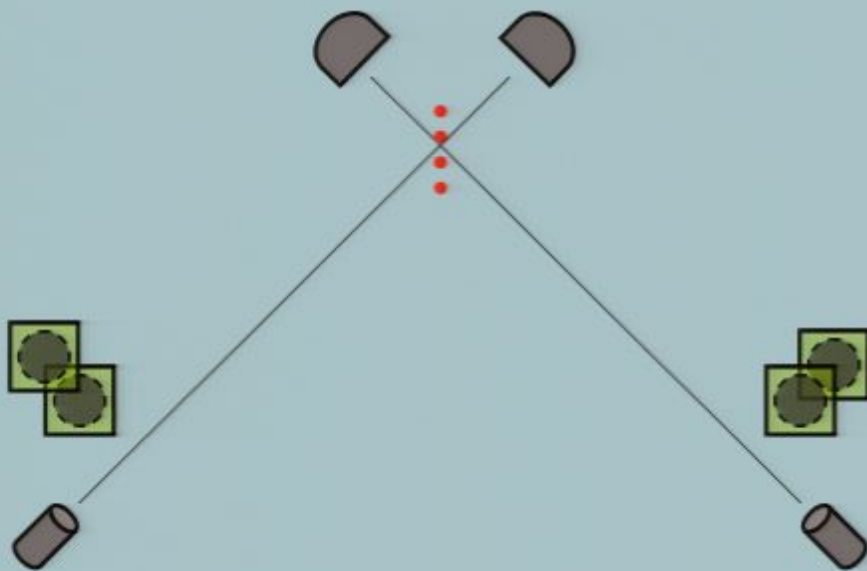
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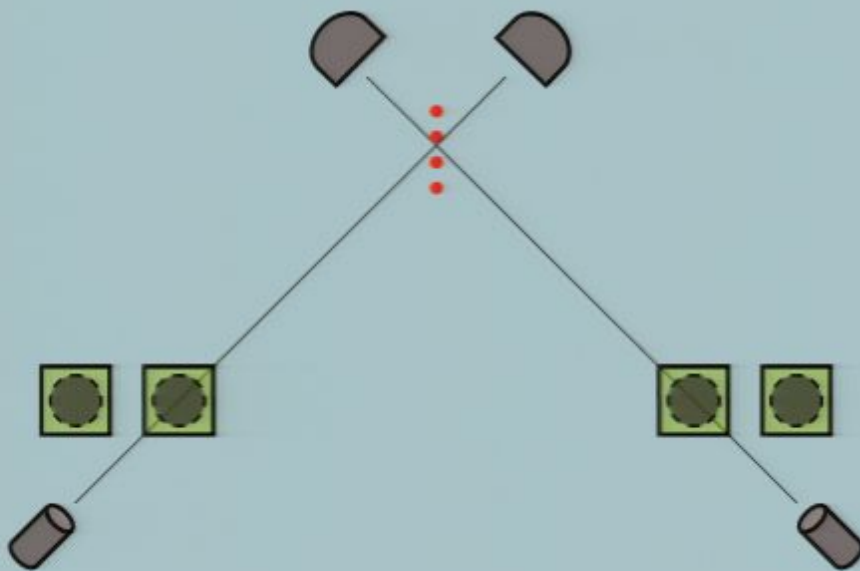
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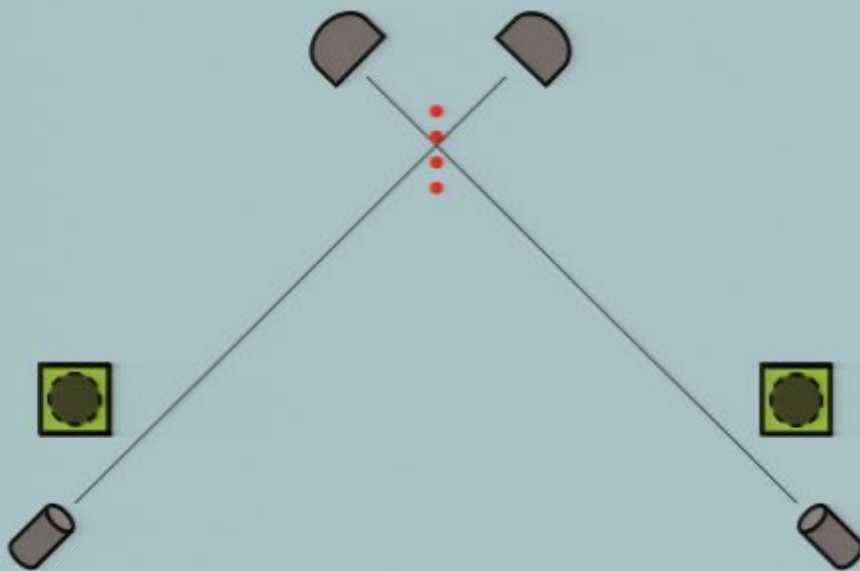
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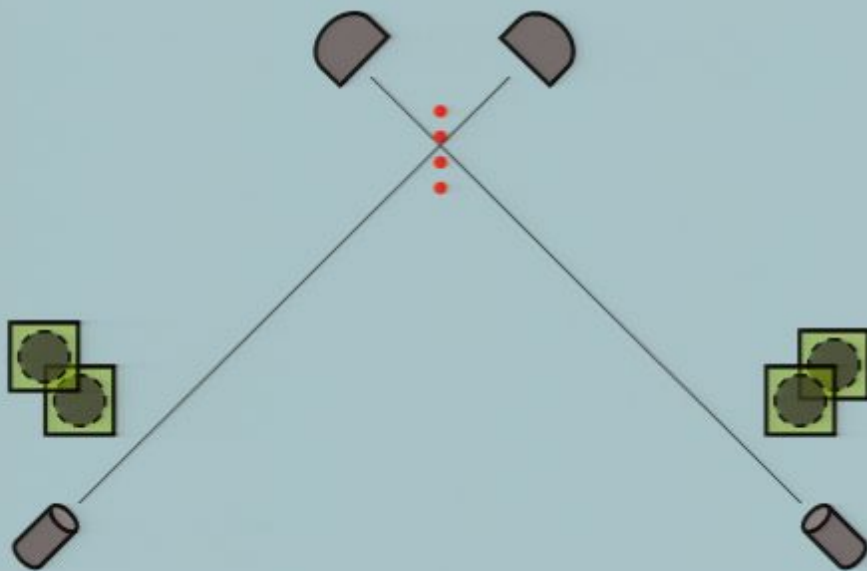
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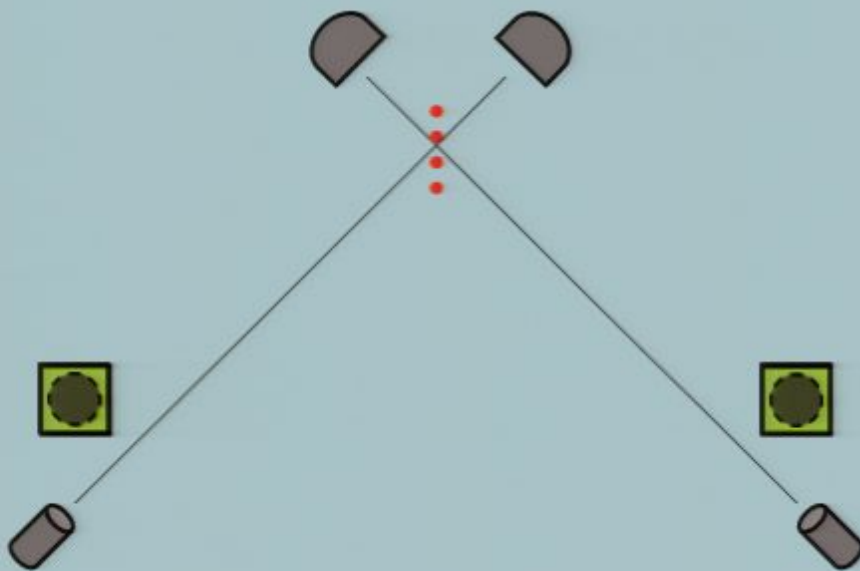


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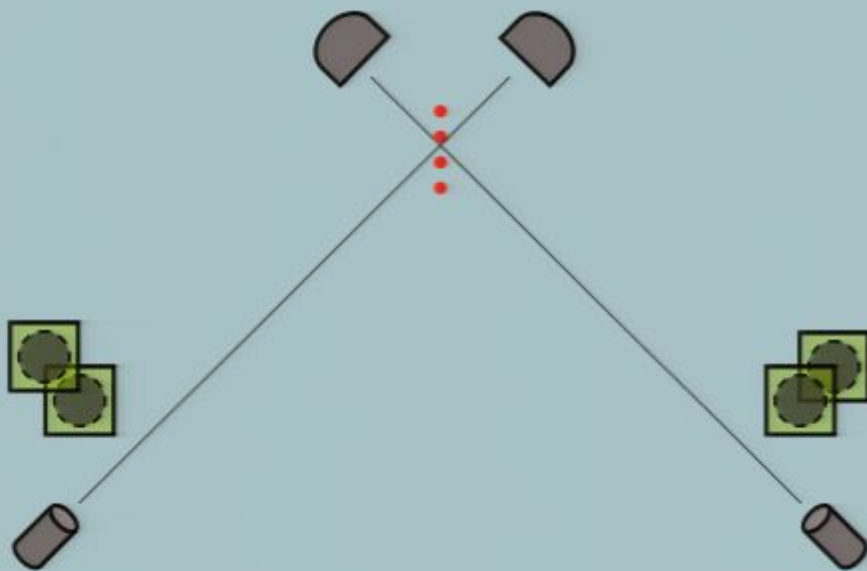
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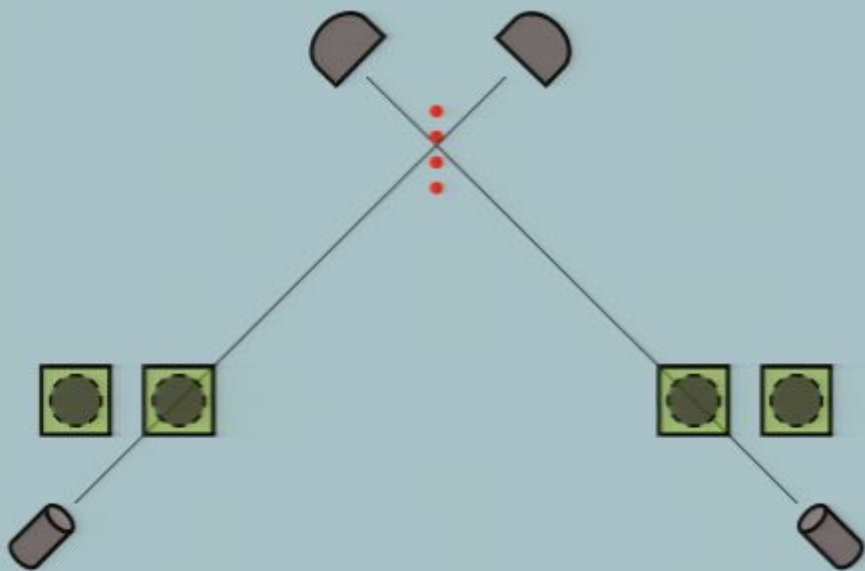
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- For  $30^\circ$  and  $-30^\circ$  directions, reunite the boxes, then split according to desired direction, and finally measure position

# The Bell Inequality Violations

The results predicted by QM:

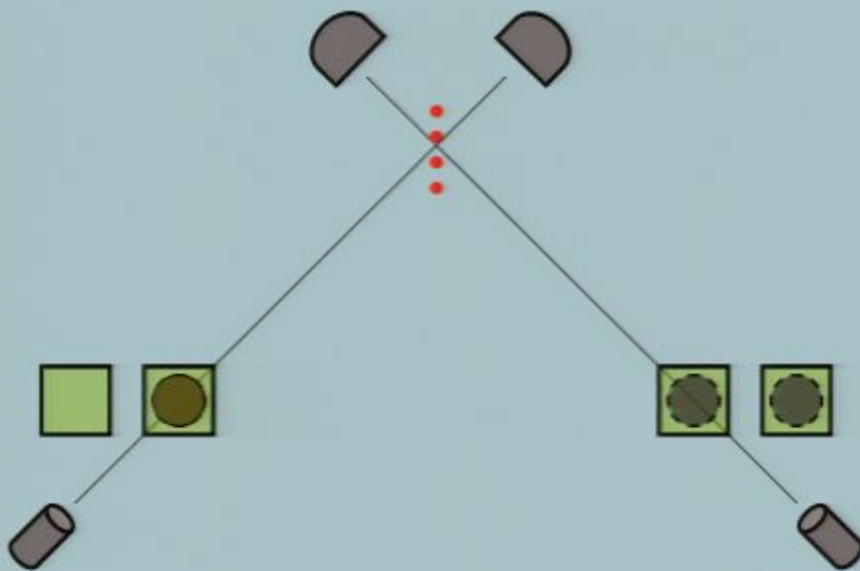
Measured Directions		Correlation
$0^{\circ}$	$0^{\circ}$	100%
$30^{\circ}$	$30^{\circ}$	100%
...		
$0^{\circ}$	$-30^{\circ}$	75%
$30^{\circ}$	$0^{\circ}$	75%
...		
$-30^{\circ}$	$30^{\circ}$	<b>25% !</b>
$30^{\circ}$	$-30^{\circ}$	<b>25% !</b>

# The Quantum Liar Paradox





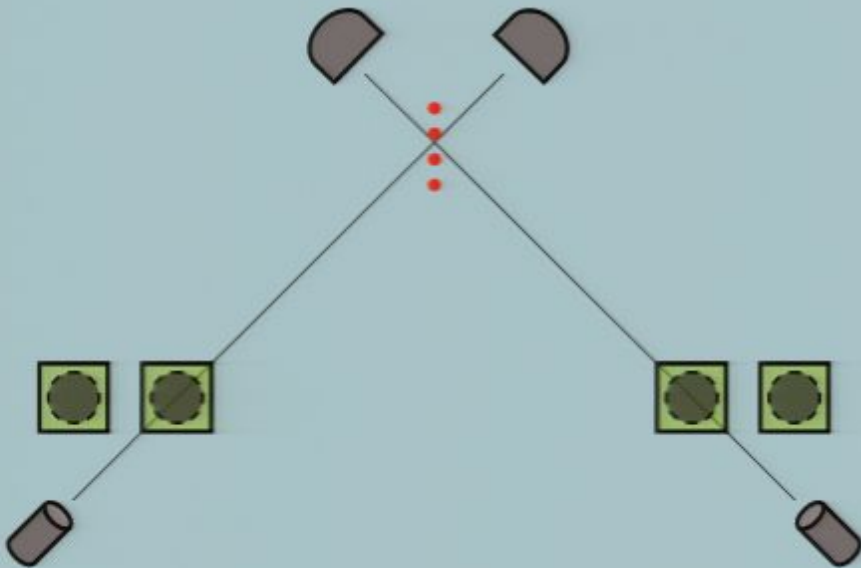
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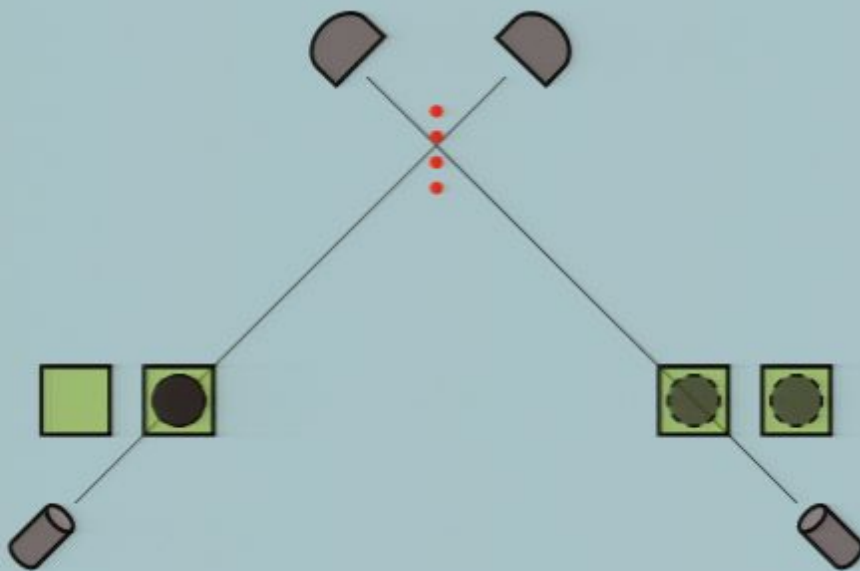
- $0^0$  direction ("which box") measurement allows only one history for the photon



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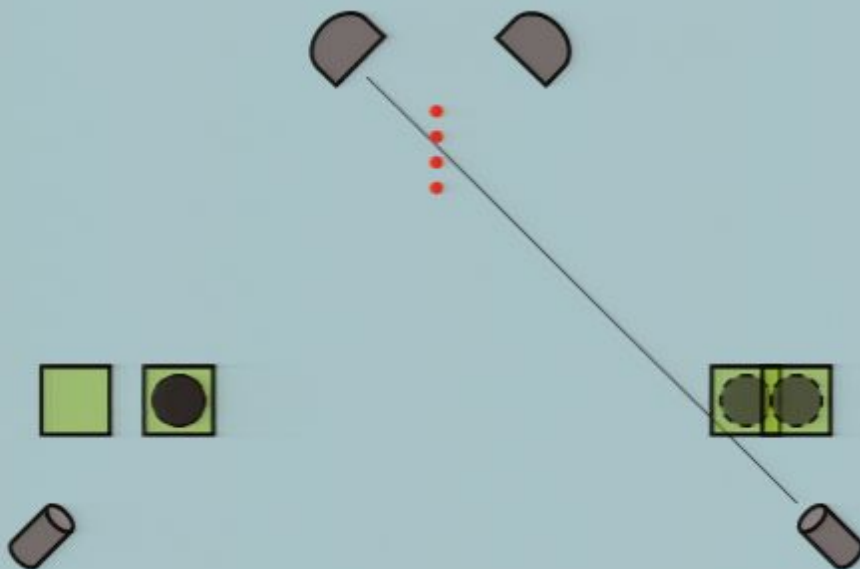


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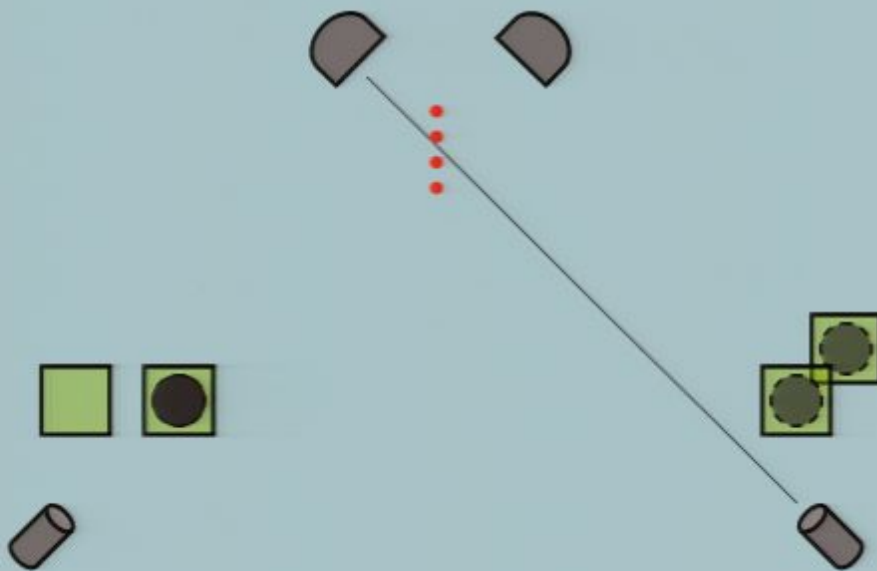
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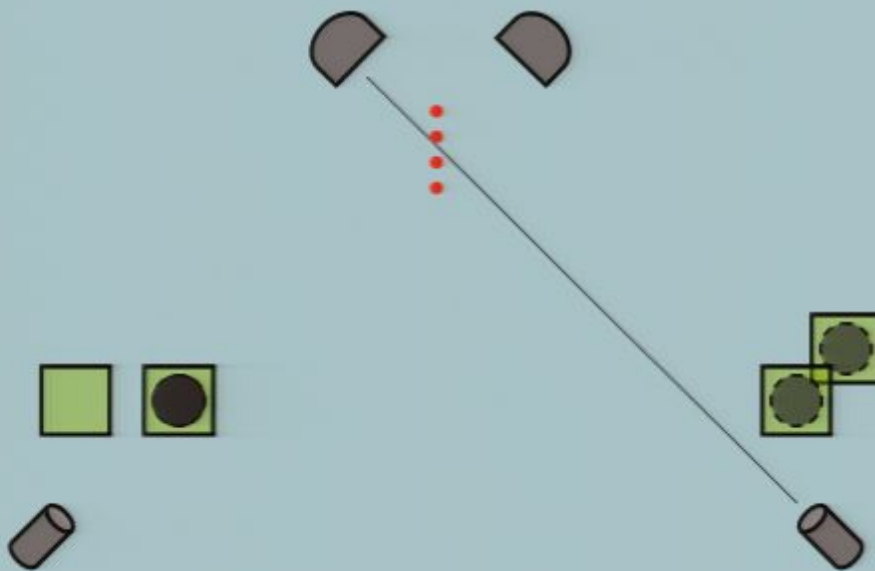
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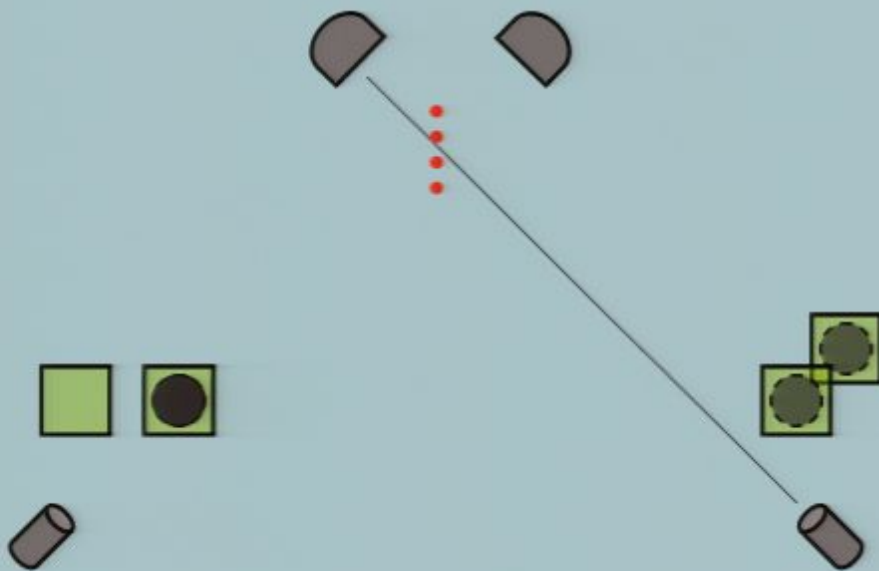
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- Here too, there are Bell Inequality violations...
- Which require a non-local effect between the left and the right atoms!



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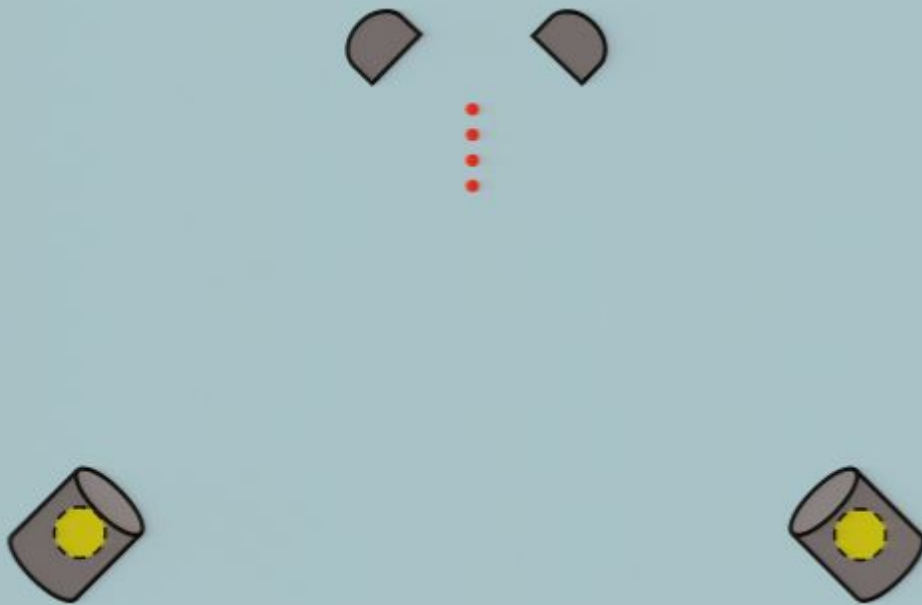
Which is logically equivalent to saying...



THIS SENTENCE HAS NEVER  
BEEN WRITTEN

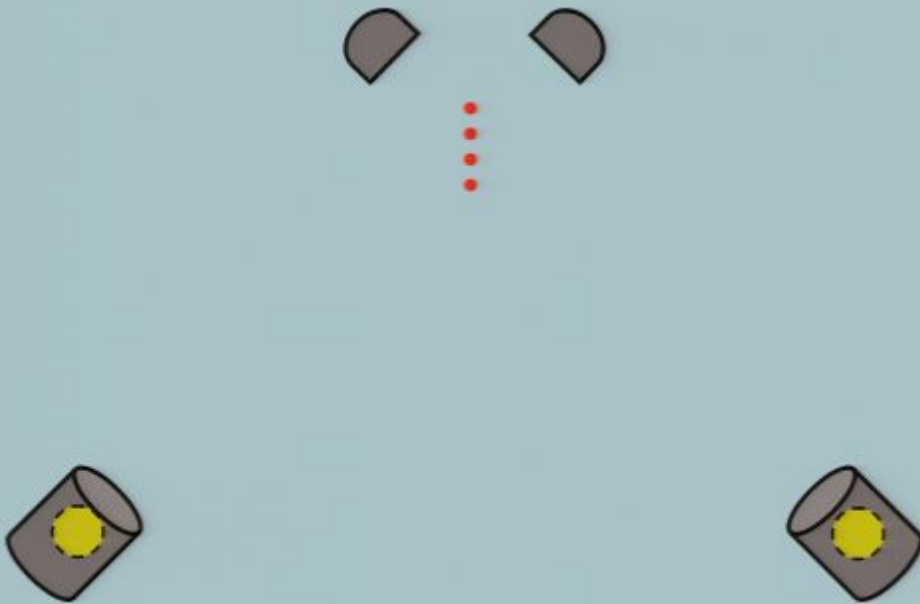
:-)

# The Quantum Liar Paradox, Zoller & Cirac's system



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- The liar paradox all over again



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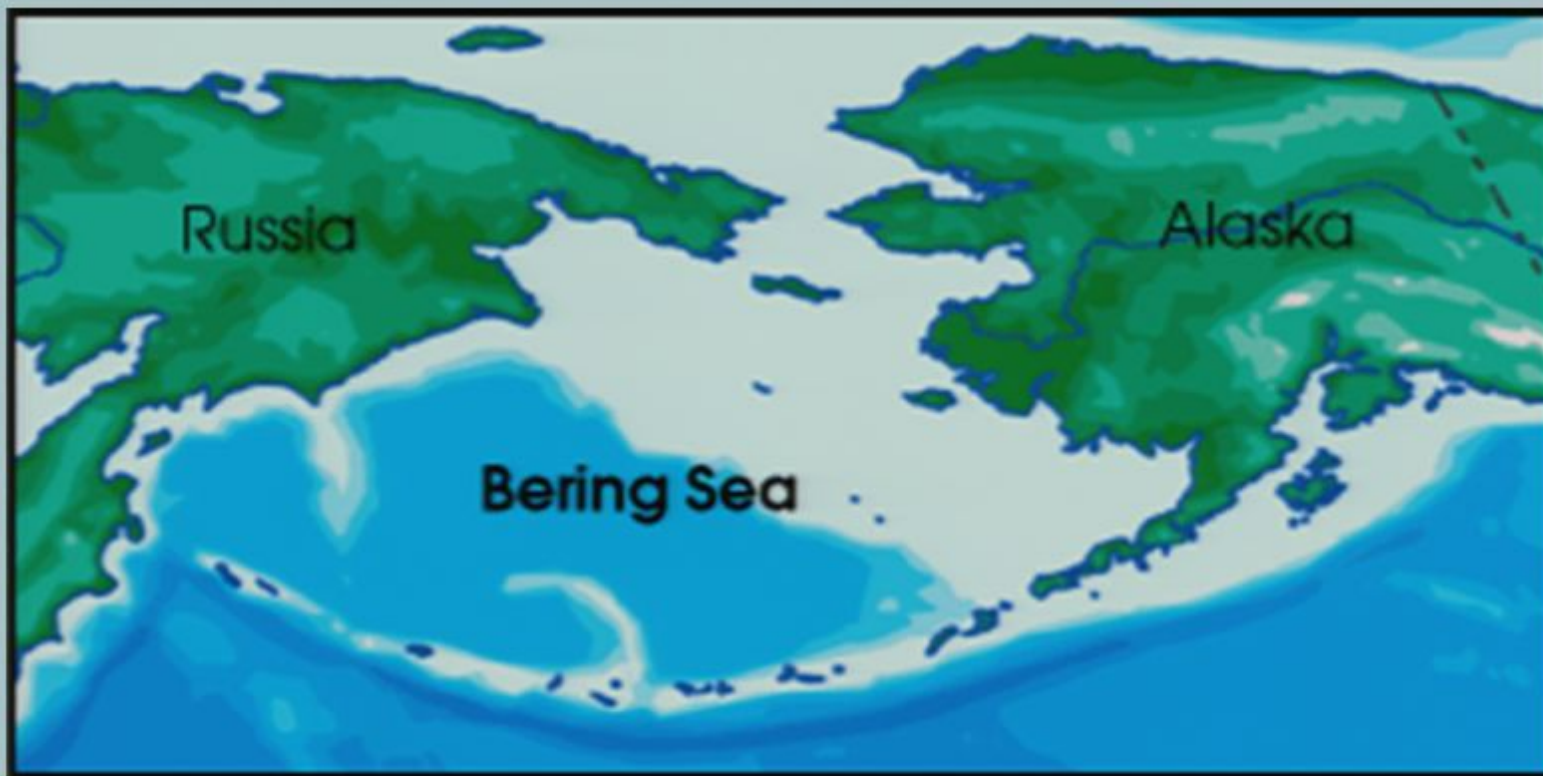
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“Every quantum event is visited twice, once by the state vector coming from the pre-selection and then again by the vector coming backwards from the post-selection” (Aharonov, personal communication).

# Большая Советская Энциклопедия



# Properties of a Quantum System between Measurements (Aharonov *et al.*)



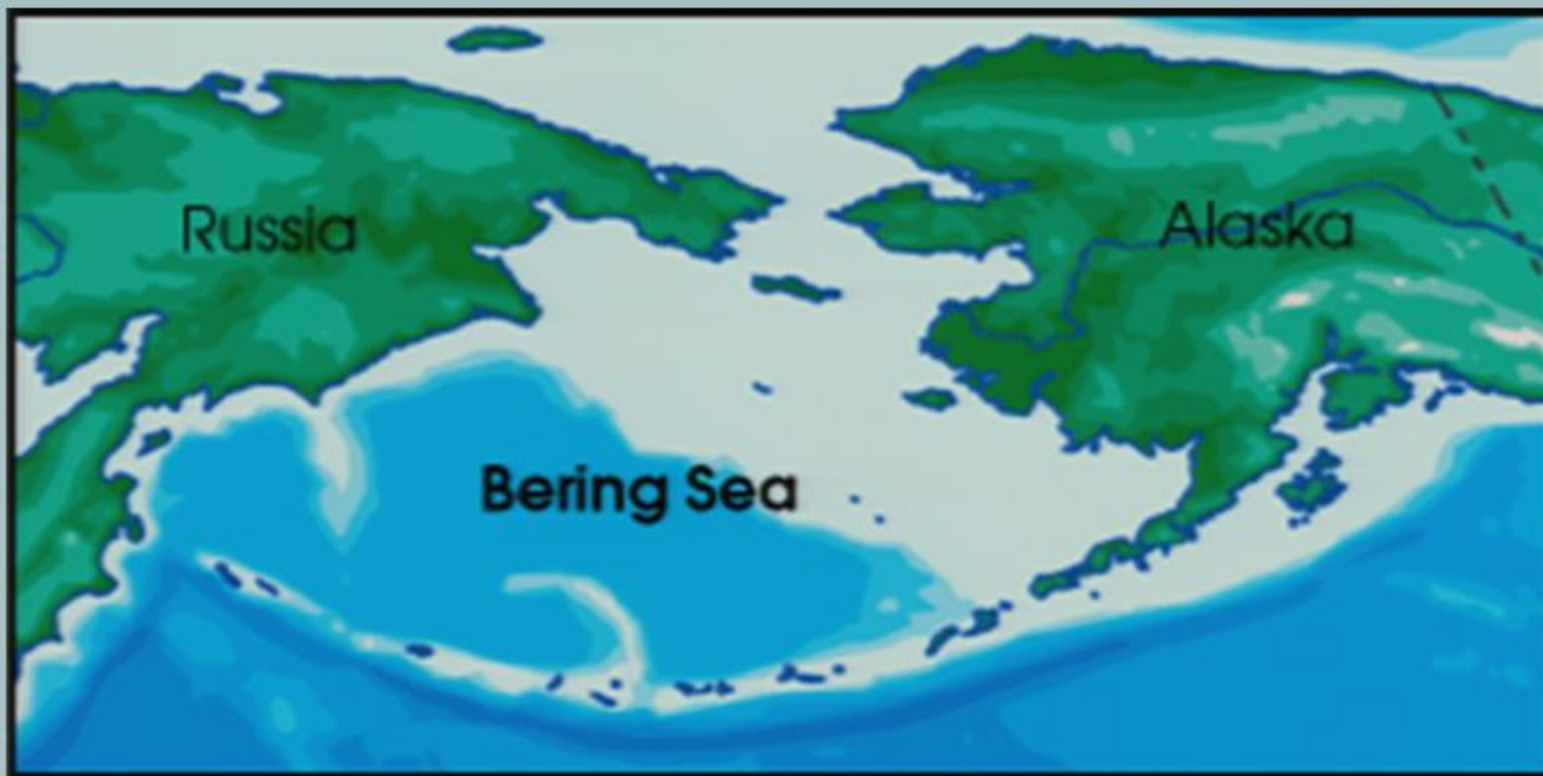
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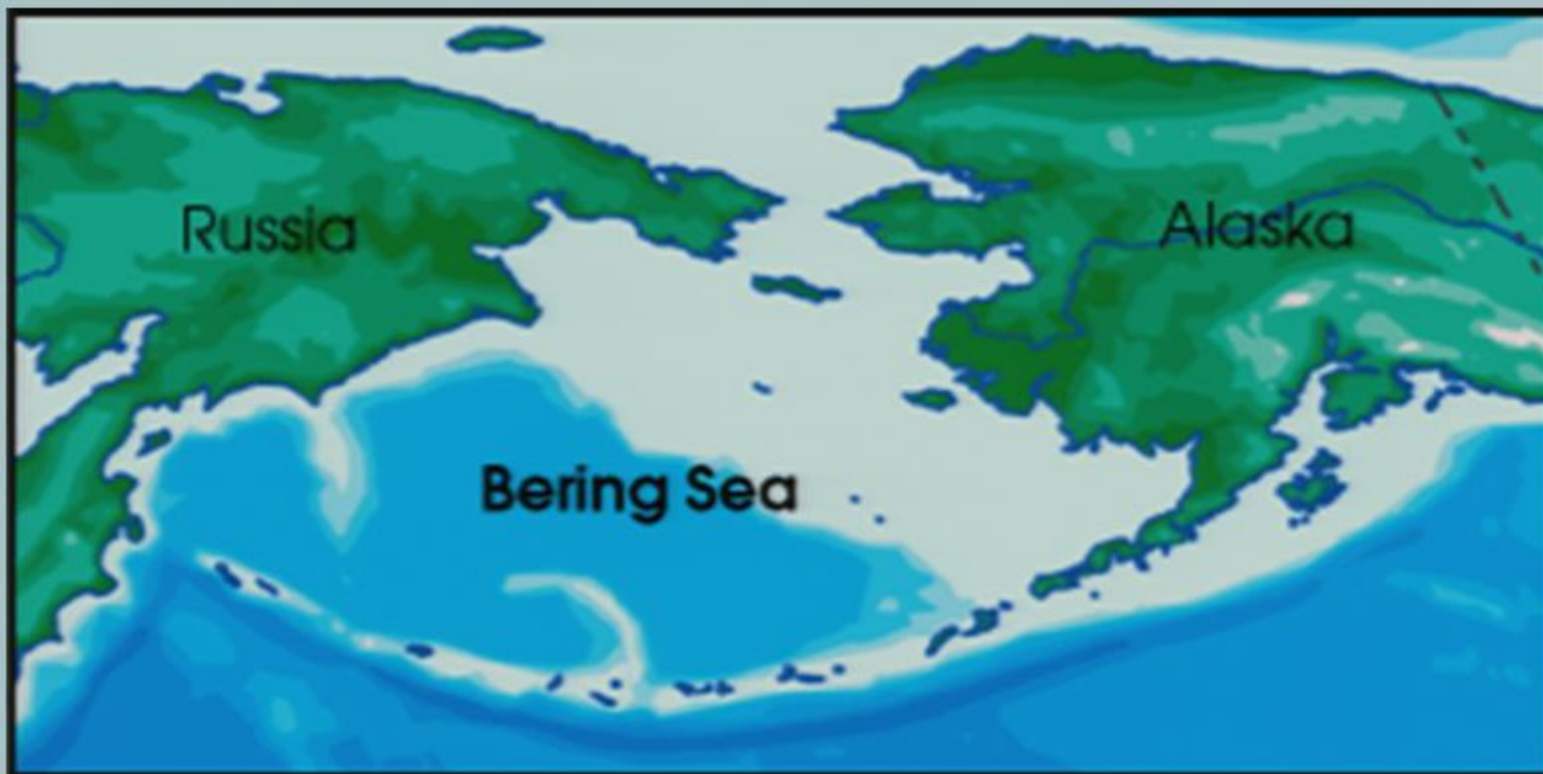


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# The Road Less Traveled

# The Assumption of Becoming

Events are created anew, one after another, in spacetime, according to their causal order. At any moment in time which one perceives as “Now,” future events are not only unknown but objectively inexistent, to be created later as the Now “advances.”

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Where there are no events, there is neither space  
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If there are no future events at any “Now,” there is  
no spacetime in the future either. Spacetime must  
be “growing” in the future direction

# A Cosmological Ring



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Spacetime is preceded and bounded by  
nothingness

# No Threat of Infinite Times

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Let presentism hold for the 4-dimensional growing  
spacetime

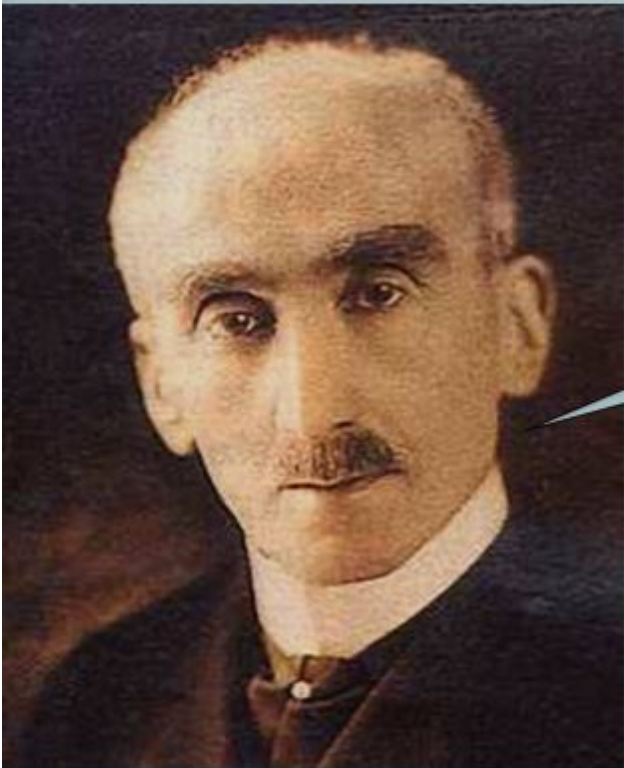


“Time and space are necessary forms of any thought and of any PowerPoint slide”





“Time and space are necessary forms of any thought”



Never spatialize time!

Block Universe



“A part of the future is emerging into a fixed local existence with each transaction, but the future is not determining the past, and the two are not locked together in a rigid embrace.”

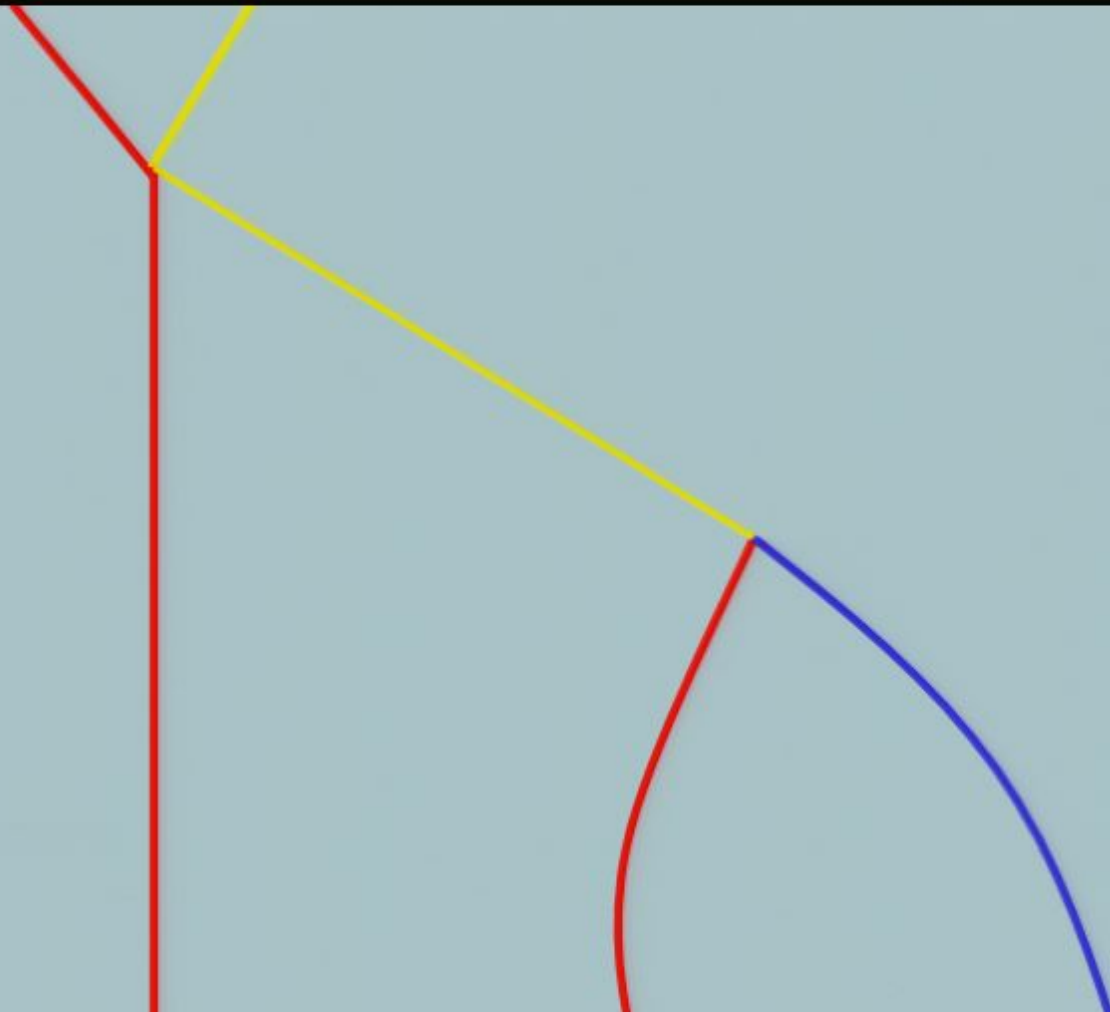
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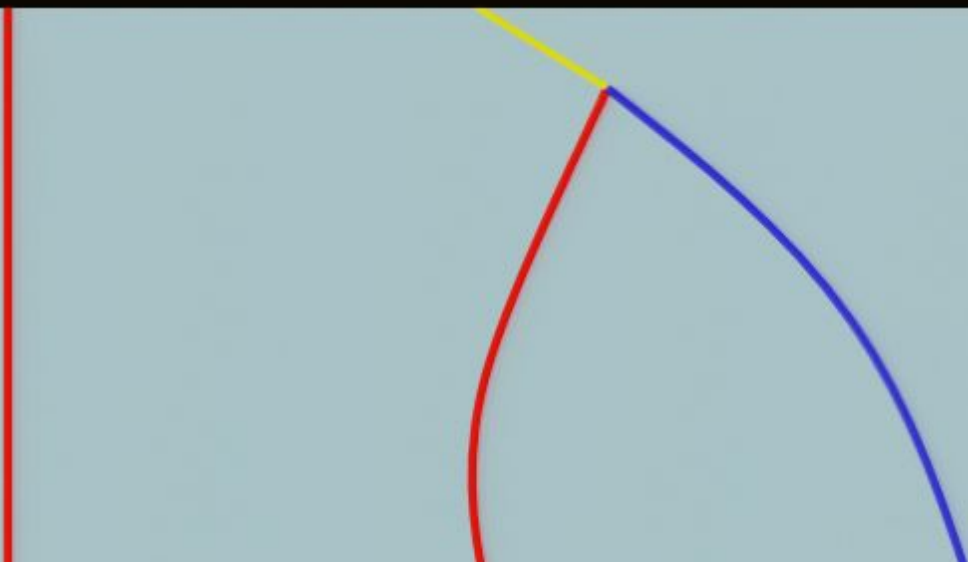
“Collapse” gives rise not only to the particle in  
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space where it could have been.

The spacetime zone associated with this  
interaction emerges only as its  
***consequence.***

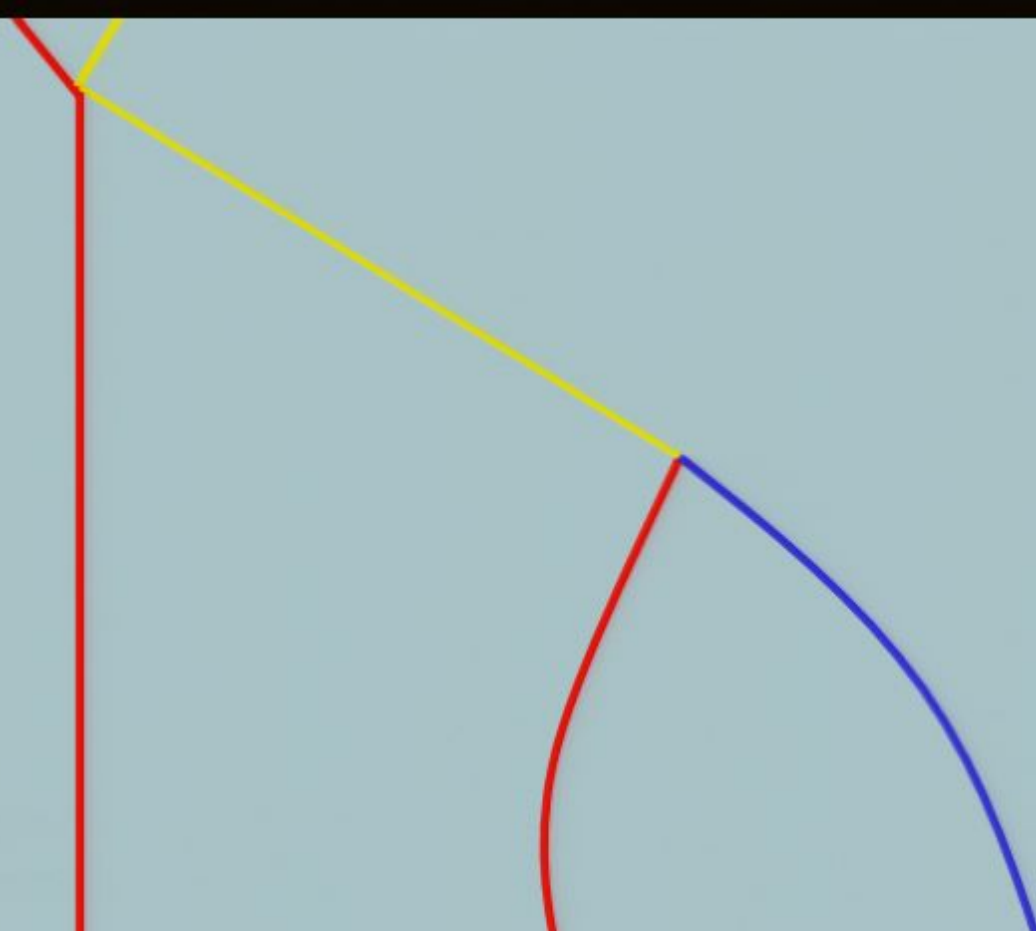


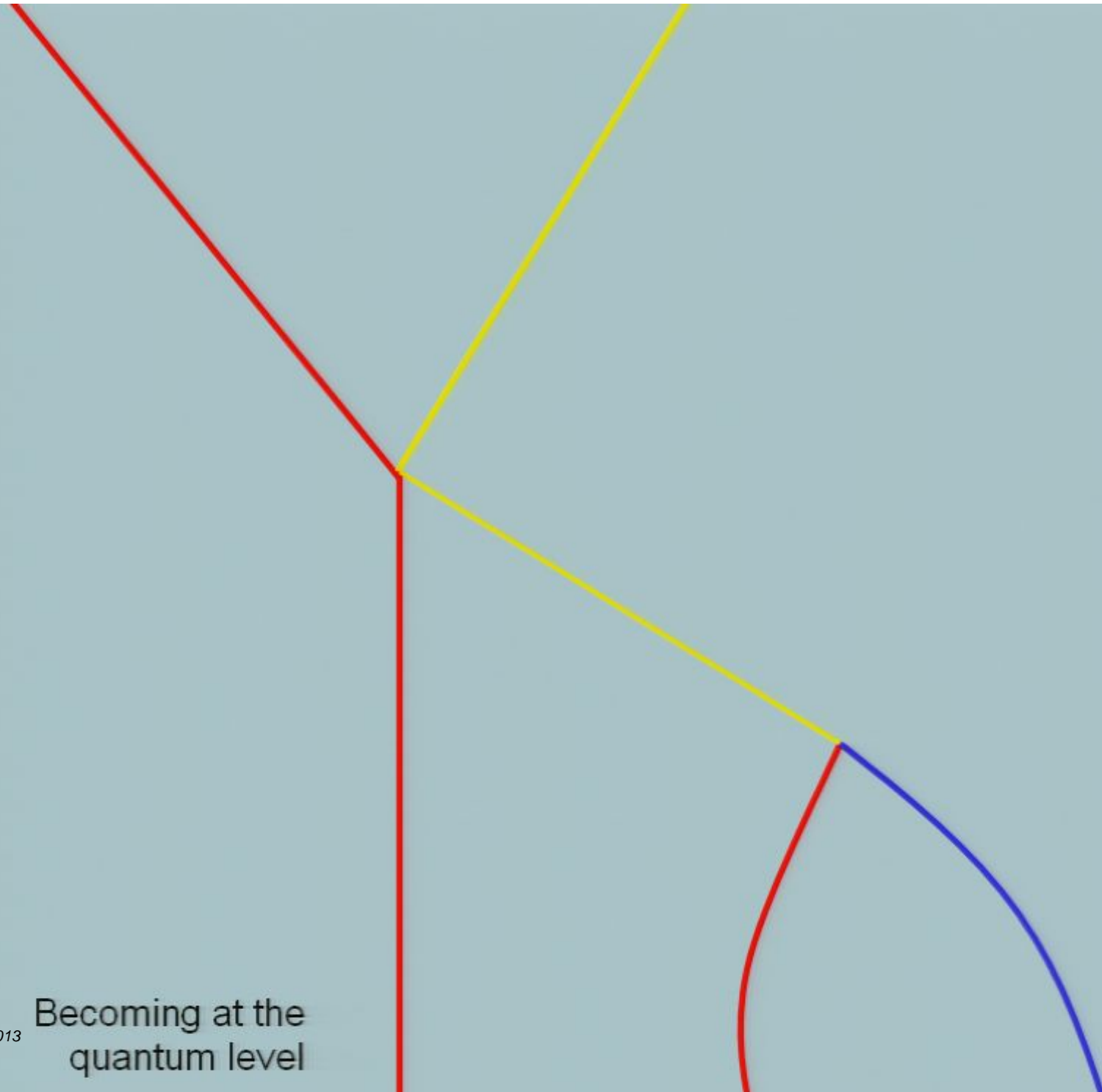


# Becoming at the quantum level



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Becoming at the  
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# Special Relativity Dynamized

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The speed of light is more basic than space and time

Because the gravitational/electromagnetic interaction precedes the relative positioning of events.



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Because the gravitational/electromagnetic interaction precedes the relative positioning of events.

Time dilation and Lorentz-Fitzgerald contraction occur due to genuine dynamical attraction between ***events***.

# General Relativity Dynamized

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Mass gives rise not only to spacetime curvature but to “dents” of the Now plane

# Consequence: The Origins of Time-Asymmetry

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Becoming is the master arrow of time



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Which creates spacetime intervals between events

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As well as the relativistic  $c$  limit

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Position, rather than being only *defined* by other positions, *emerges* due to the pre-spacetime interaction with these objects.

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Hence attraction and repulsion

*A Research Program:*

*Take all pre-big-bang scenarios and  
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*Take all pre-big-bang scenarios and  
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*E.g., Compactification as the mechanism  
for quantum collapse*

# The Road Less Traveled





The Road Less Traveled

**Has Many Forks**

What a pity to die at the dawn of relativity!

(Herman Minkowski, 1909)

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