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
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Hebrew University

Outline

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- **Becoming, Reality's Most Evaded Element**

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Time: The Common View

Events Become and Go, One by One

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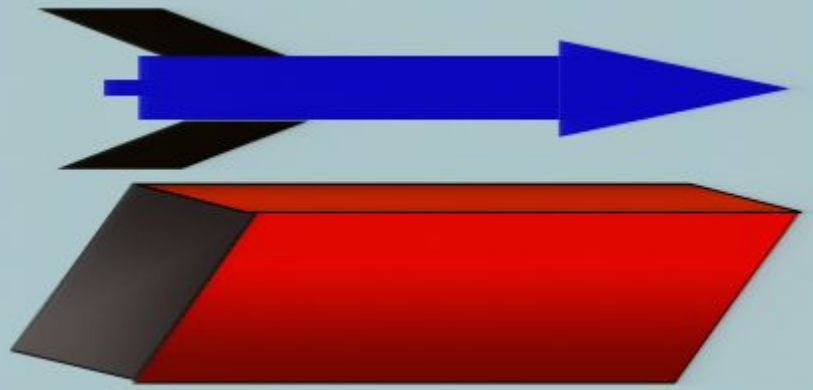
Relativistic Contraction is a Consequence of the "Coexistence" of Past and Future States



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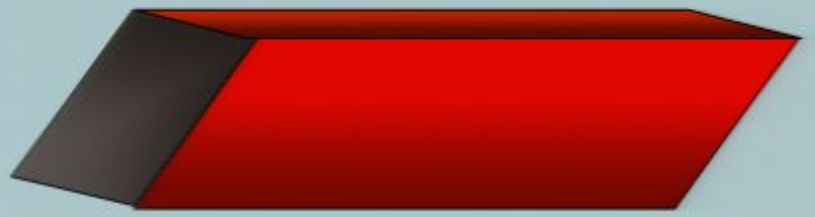

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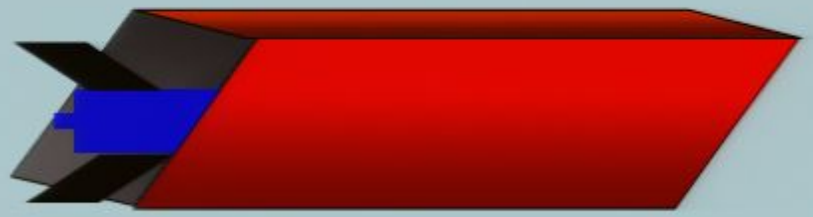

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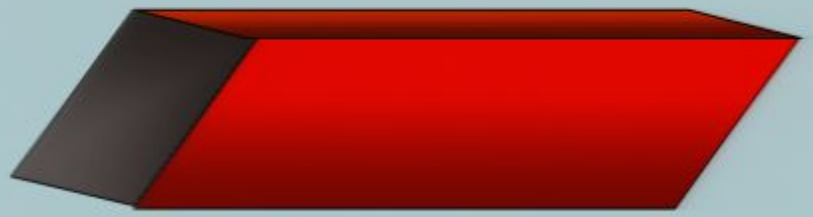

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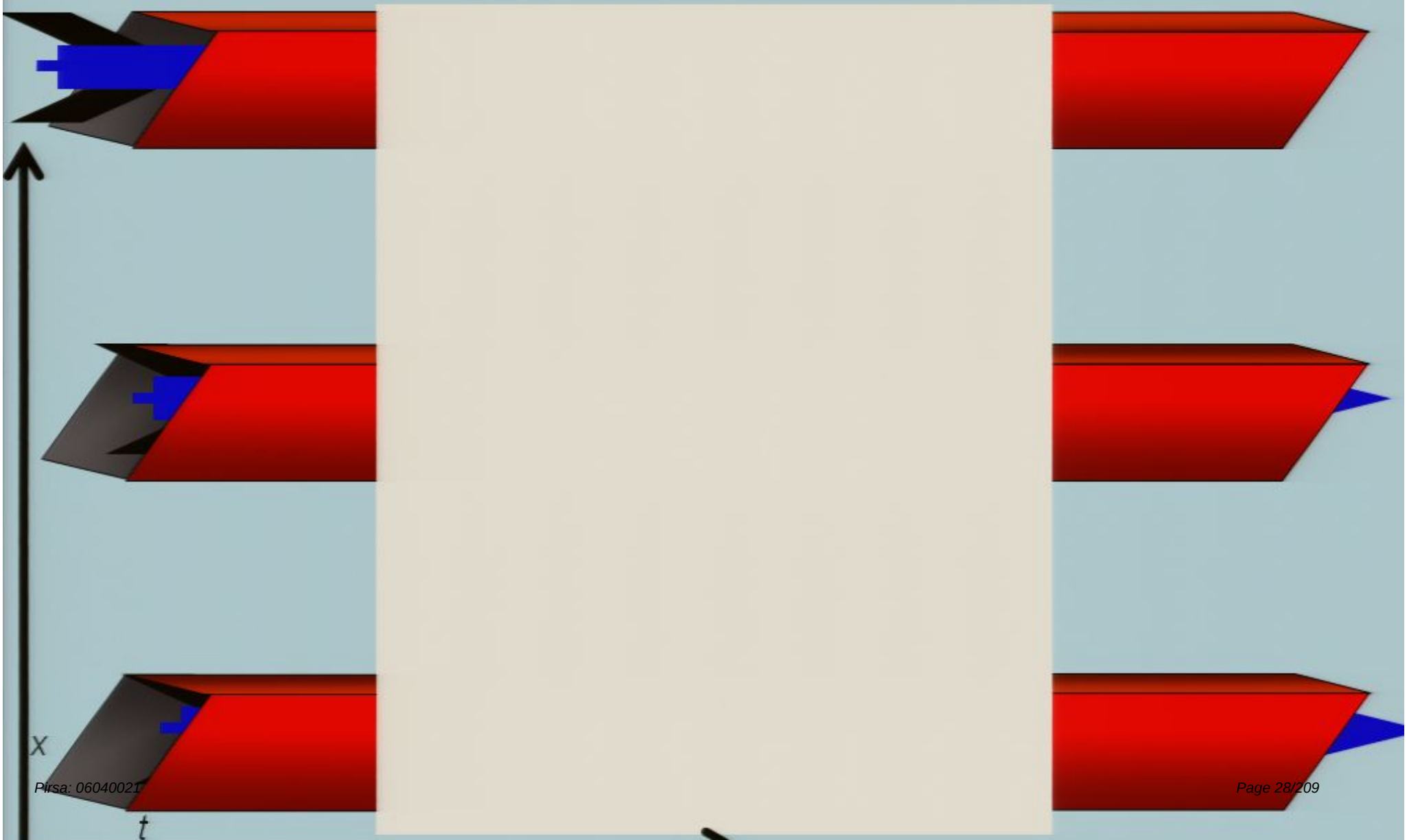

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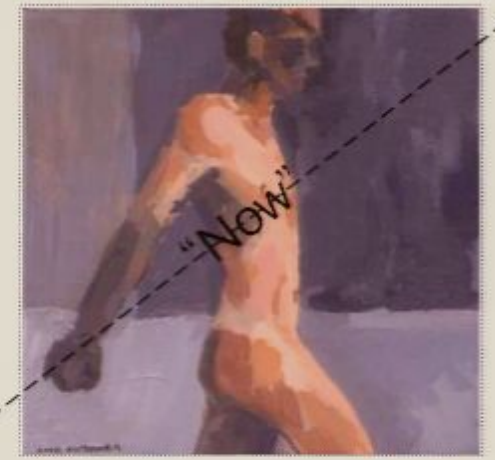

x

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The Block Universe Account of Time

All events – past, present and future – have the same degree of existence. There is no privileged "Now."

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.

Why Most Physicists Deny Becoming

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2. It seems to entail absolute simultaneity

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Lavishness:

- Extra spatial dimensions
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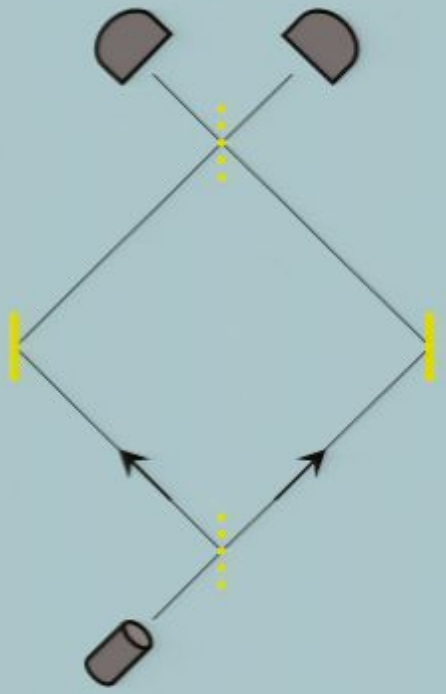
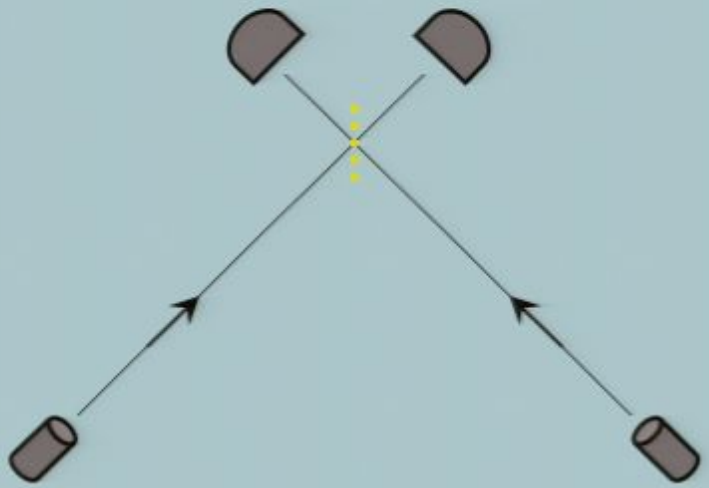
- Multiverse
- Etc.

All within the Block Universe!

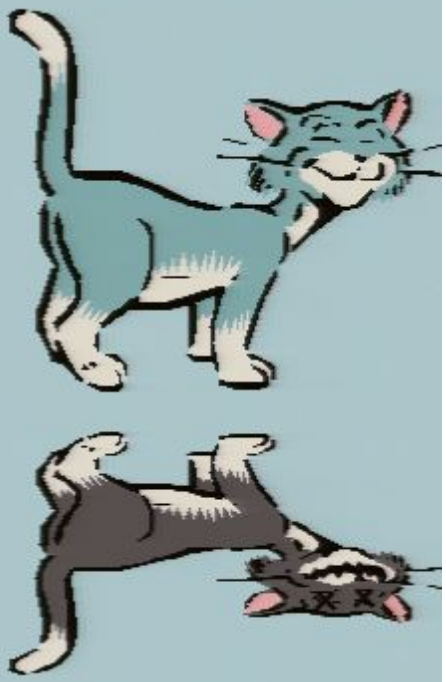
Quantum Temporal Peculiarities



Delayed Choice



HBT Experiment



Schrödinger's cat

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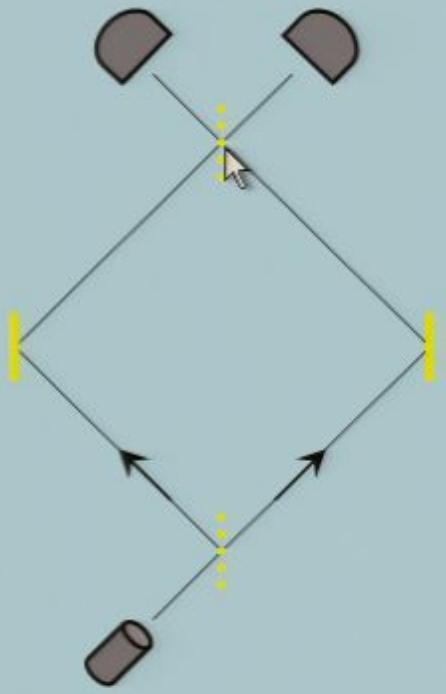

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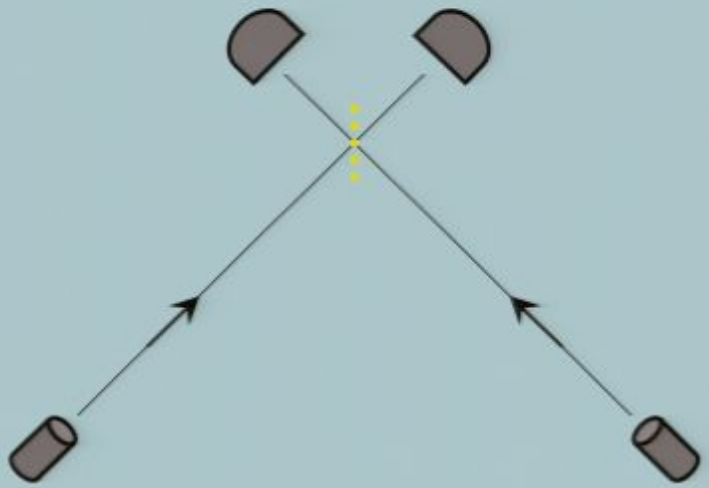

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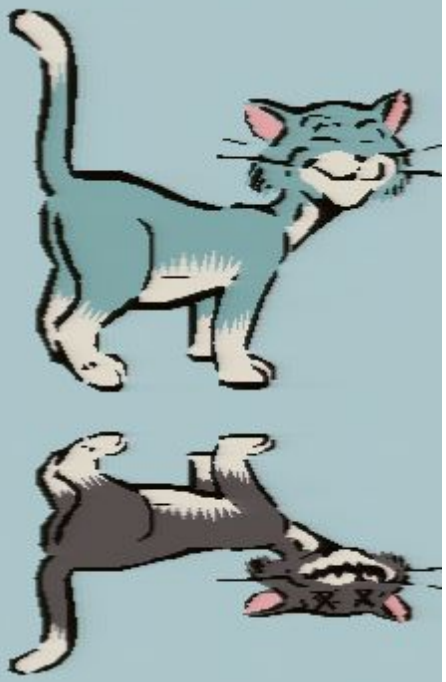

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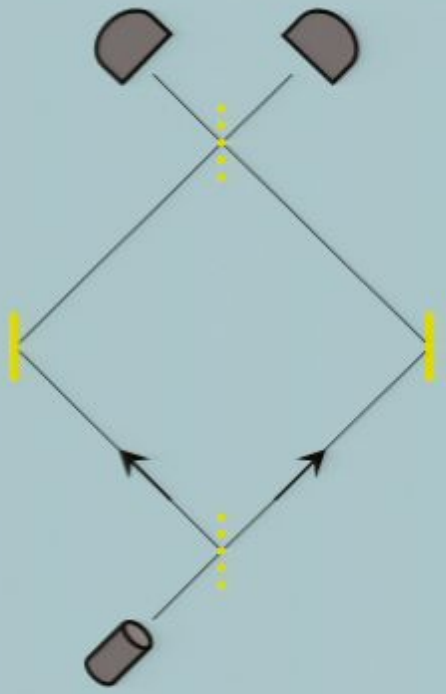

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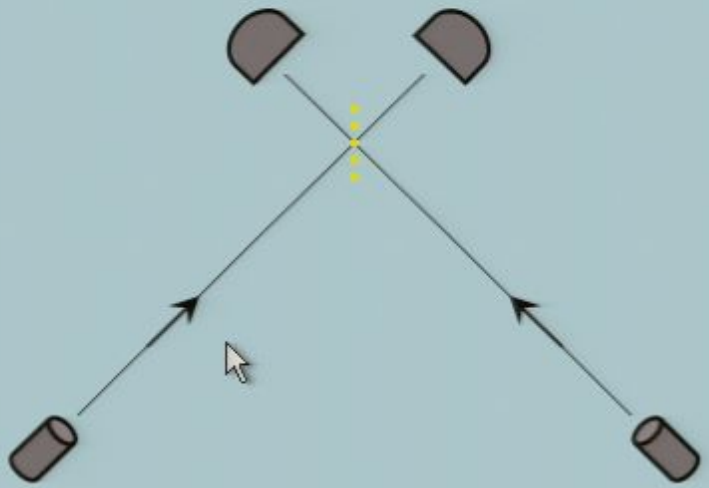

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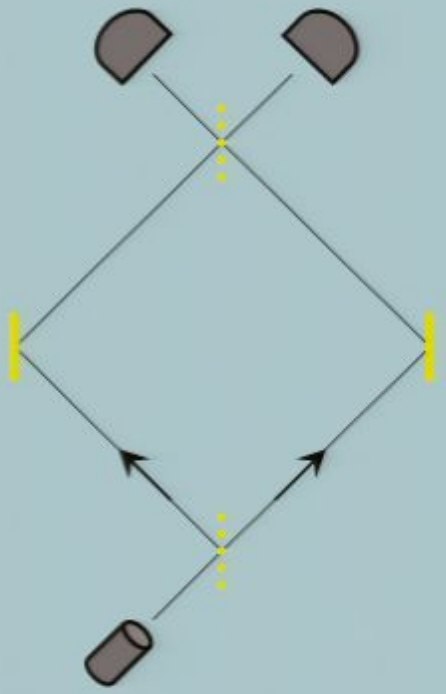

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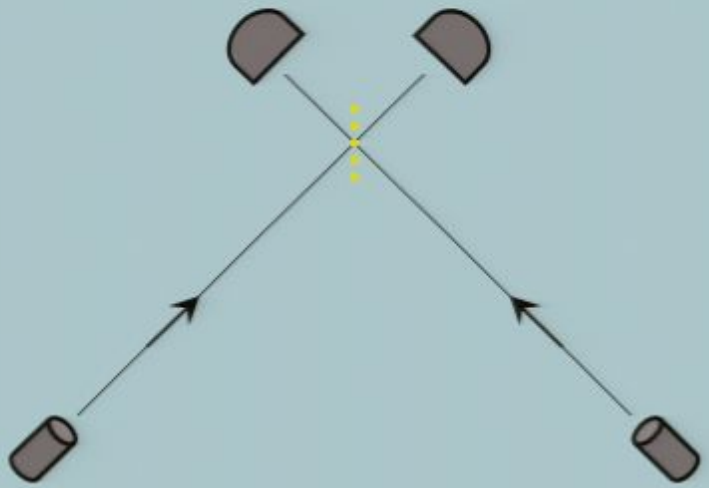

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Schrödinger's Cat as a Temporal Paradox

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t_1: Lethal event occurring or not occurring

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t_f: Cat dead and decomposing

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OR

t_f: Cat dead and decomposing

t_f: Cat alive, but lean and unhappy

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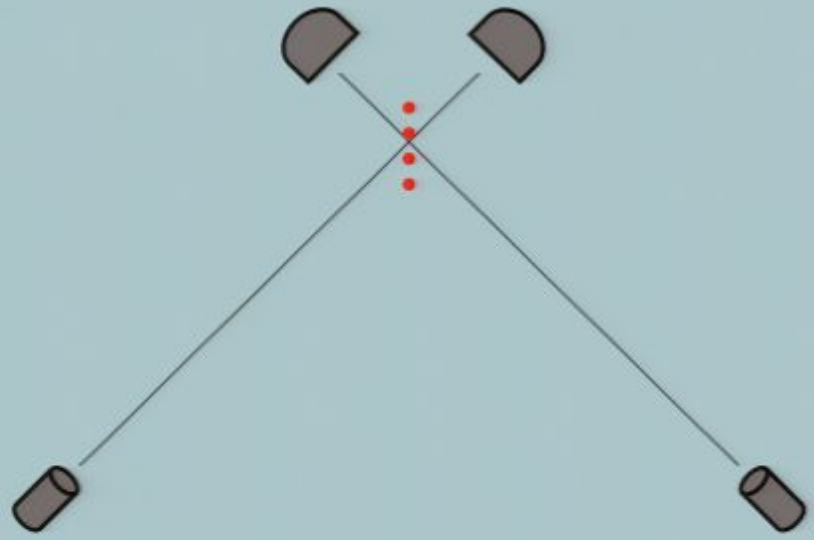
Hanbury-Brown-Twiss Effect:

- (HBT, 1958) Interference of two distant sources:



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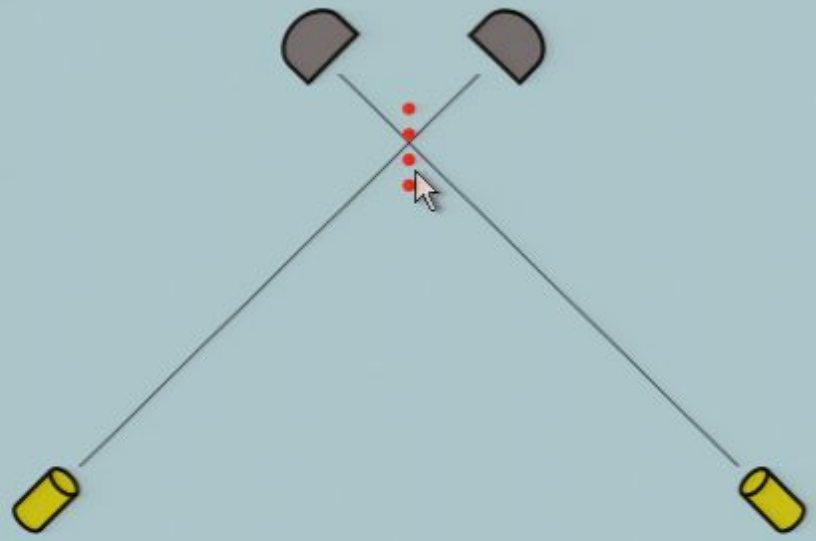

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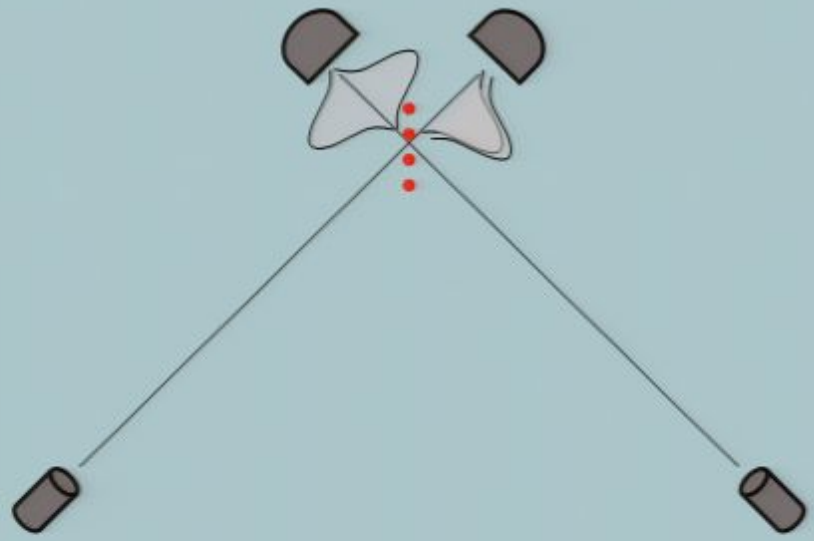

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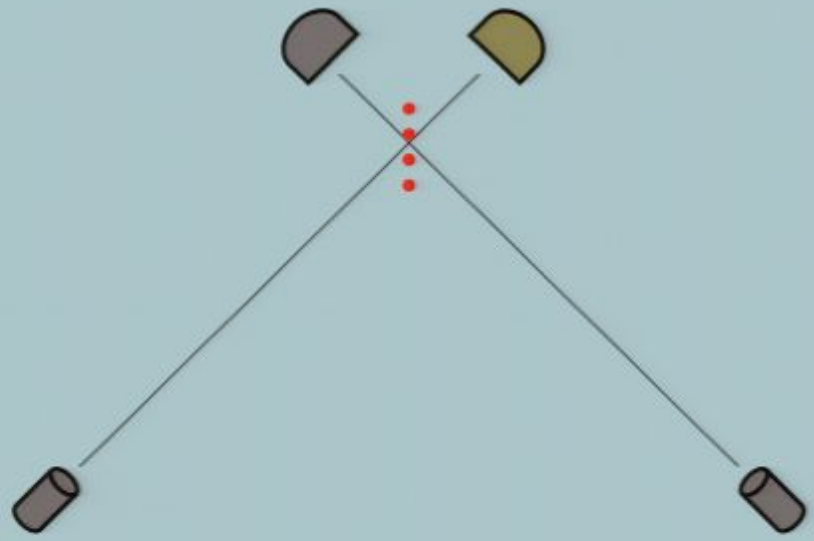

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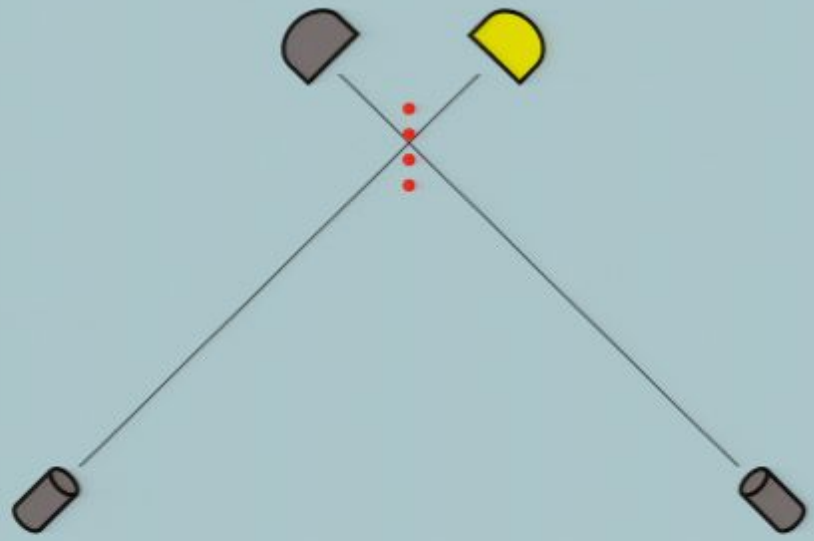

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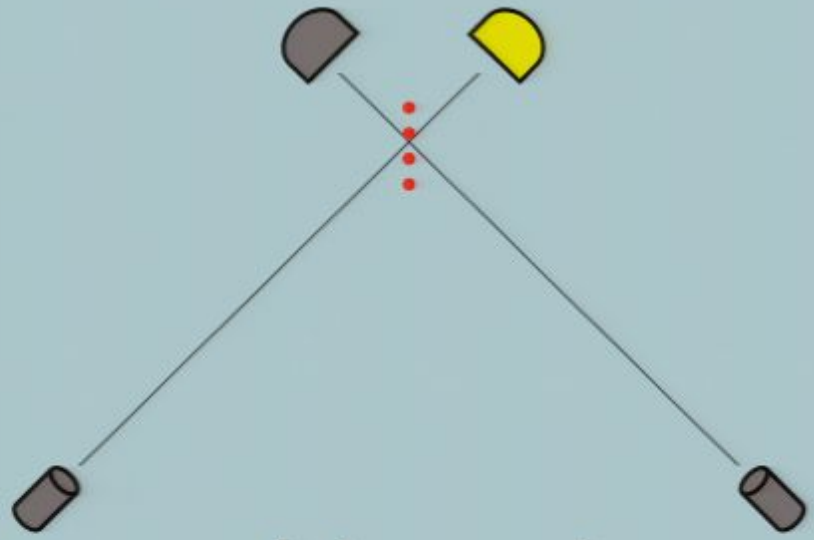
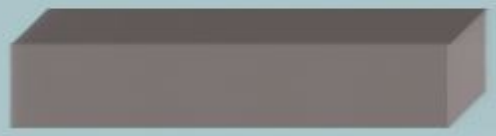


- Even when the sources are so weak to produce a single photon at a time!

The Hardy Atom



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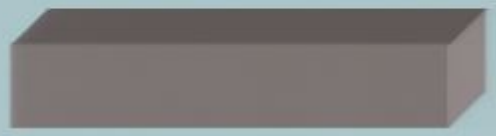

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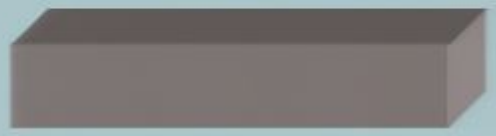

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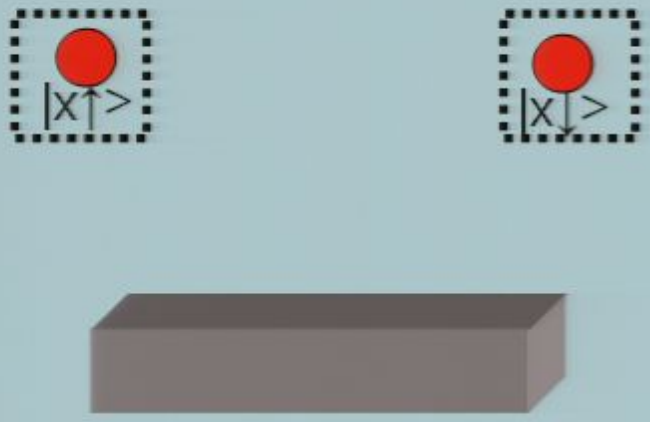

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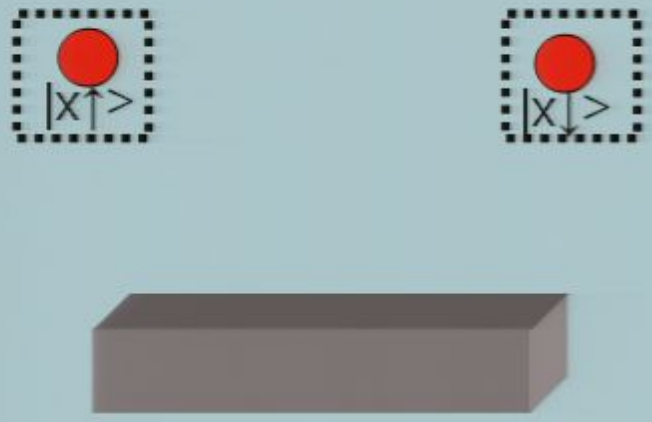

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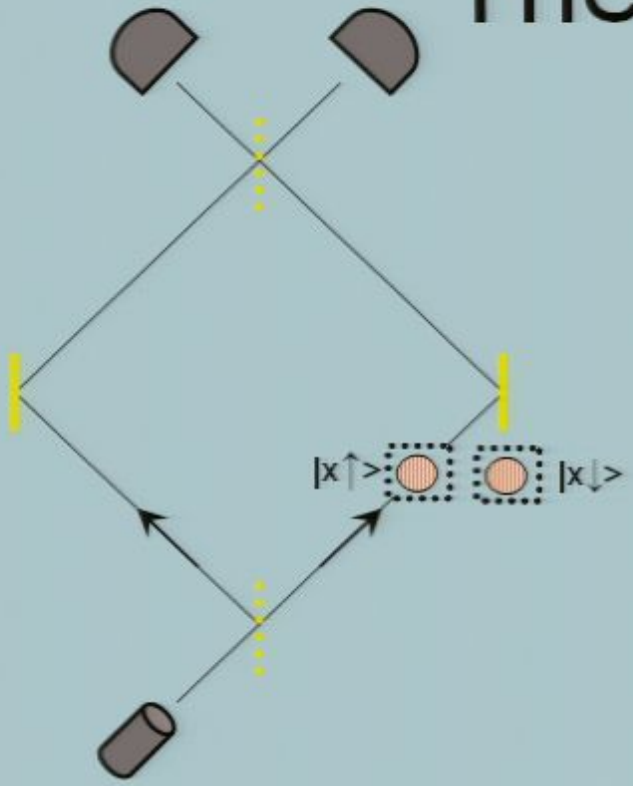

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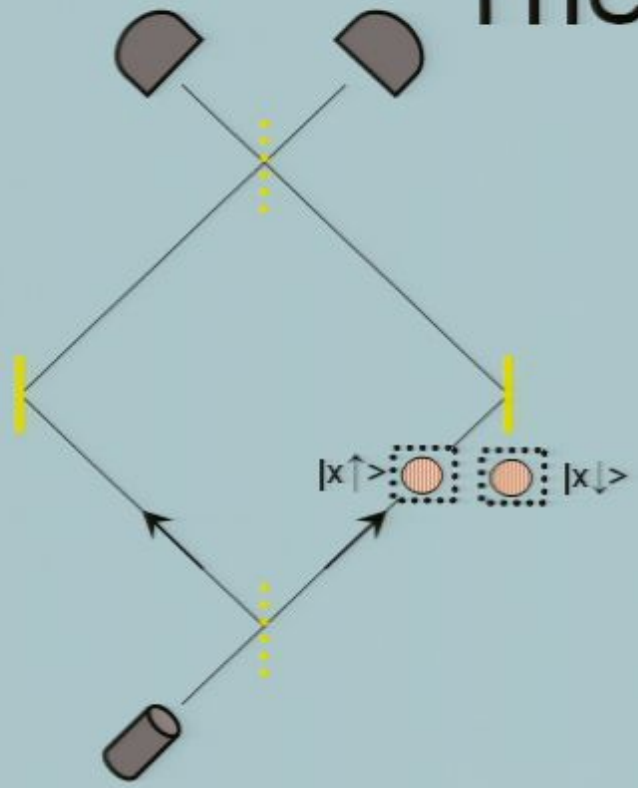

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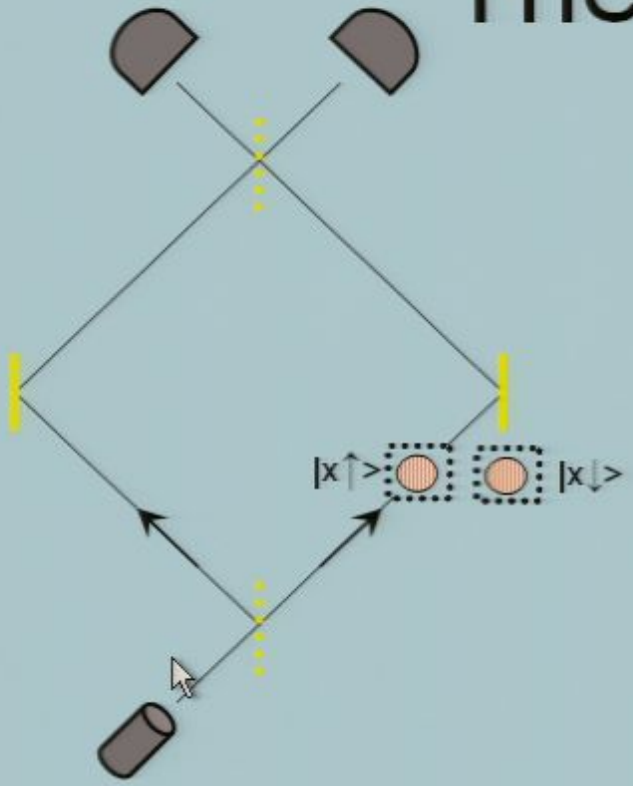

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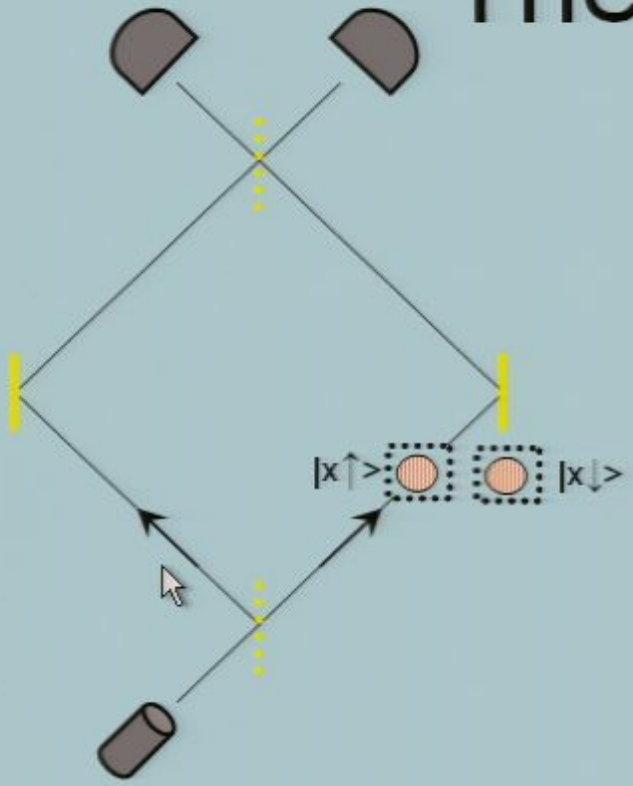

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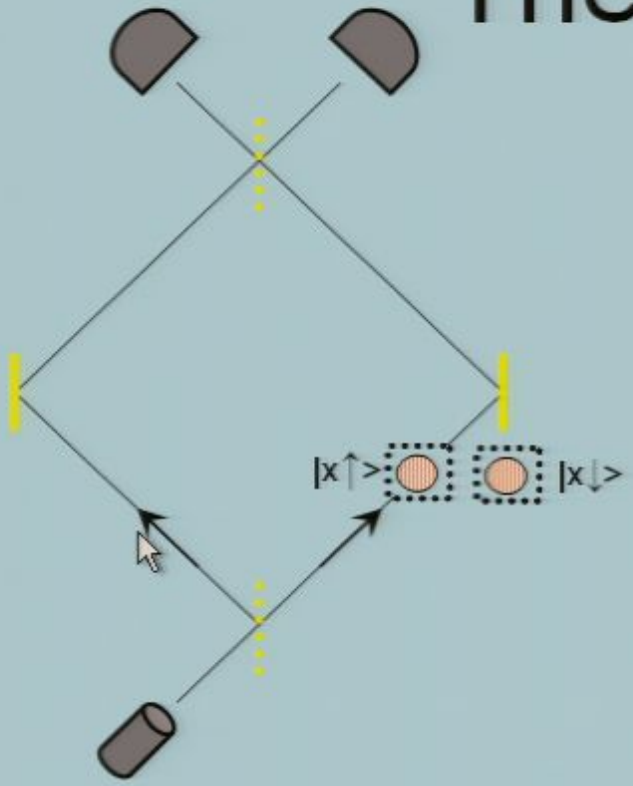

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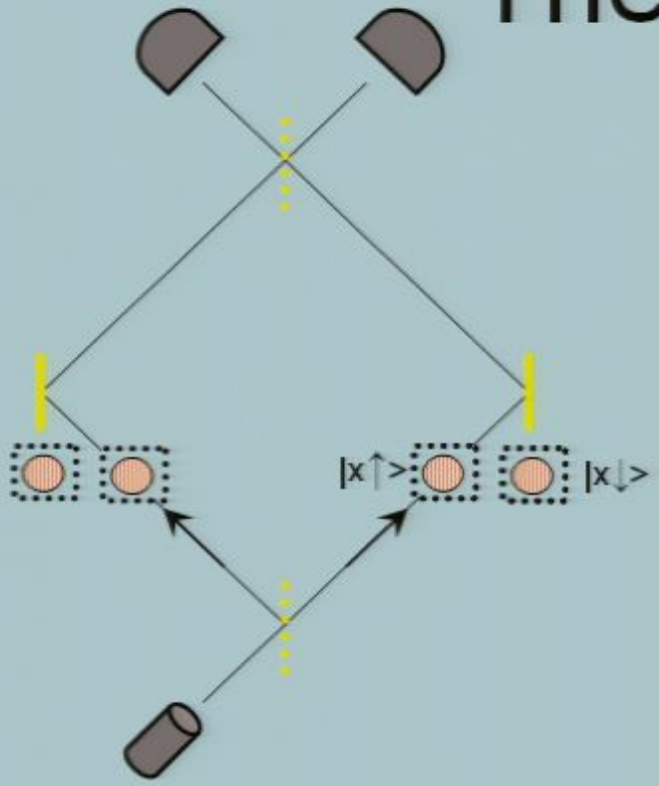

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7. Two Hardy atoms can be entangled into an EPR pair

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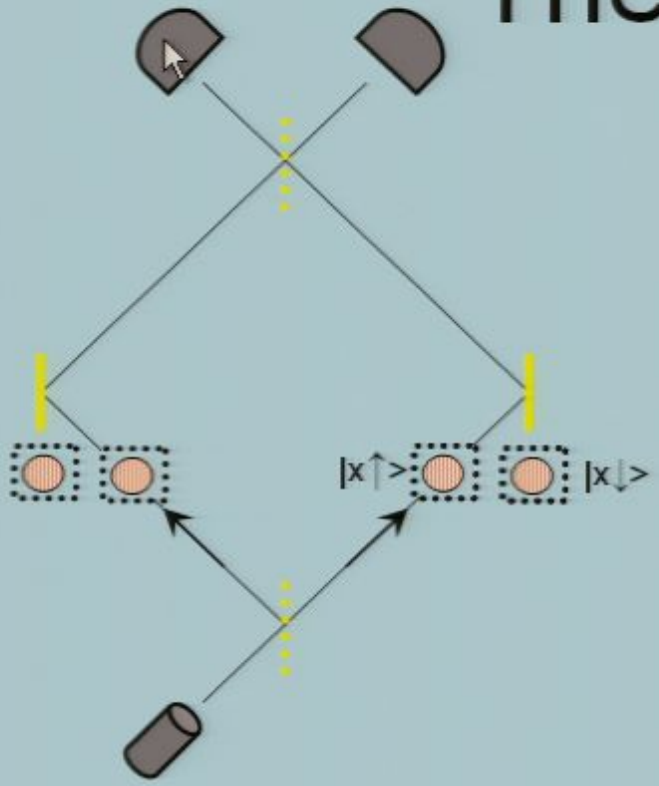

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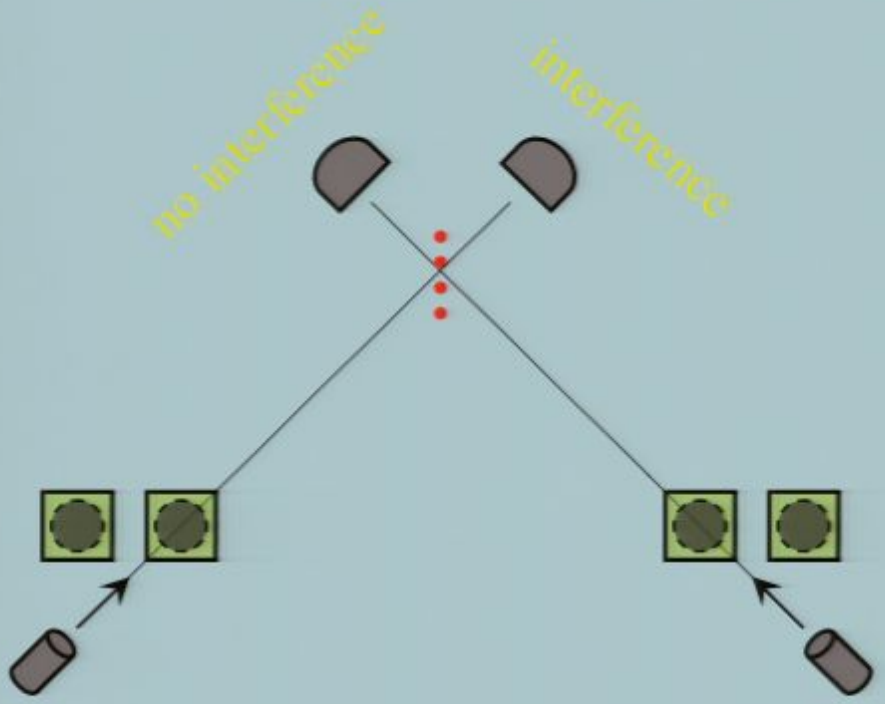
2. It is then split by a Stern-Gerlach Magnet into $|x\downarrow\rangle$ and $|x\uparrow\rangle$
3. The two halves of the wave function are confined into boxes
4. That are transparent for photons but opaque for the atoms
5. One of the boxes is placed on one arm of an interferometer
6. Such that if the atom is in that box and if the photon passes in that arm, absorption occurs with probability 1.
7. Two Hardy atoms can be entangled into an EPR pair

Time-Reversed EPR

(Elitzur, Dolev & Zeilinger 2001)



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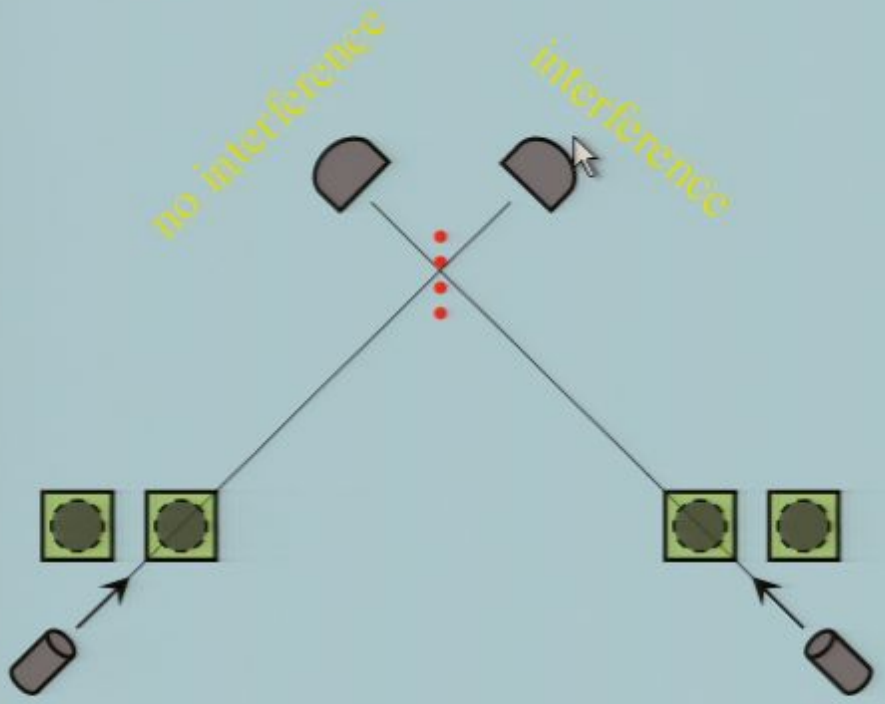

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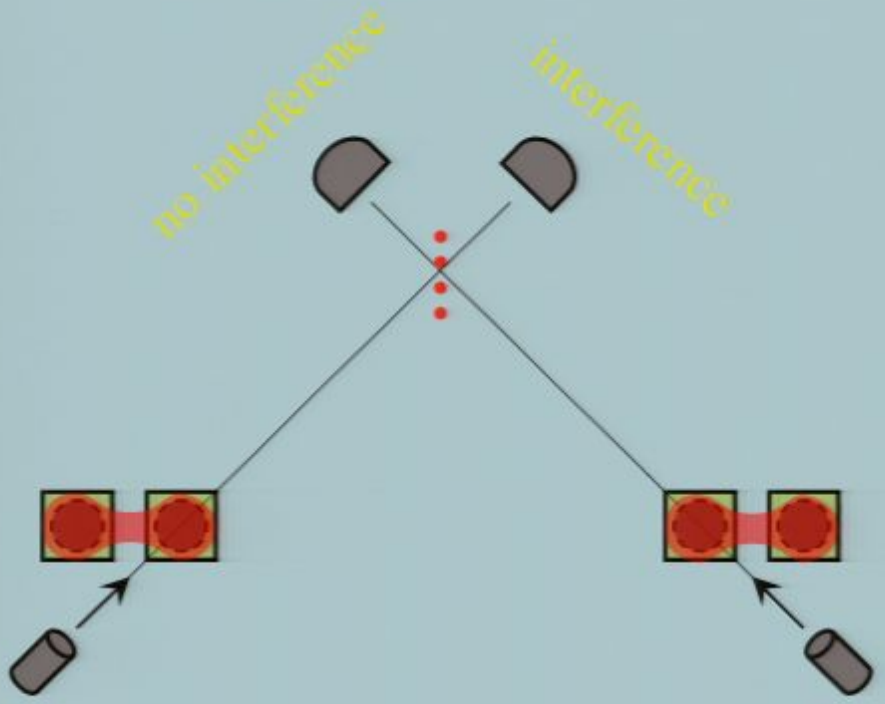

1. Two Hardy atoms in x-spin superposition (but not entangled)

$$\frac{1}{2}\left(|x_1\uparrow\rangle+i|x_1\downarrow\rangle\right)\left(|x_2\downarrow\rangle+i|x_2\uparrow\rangle\right)$$

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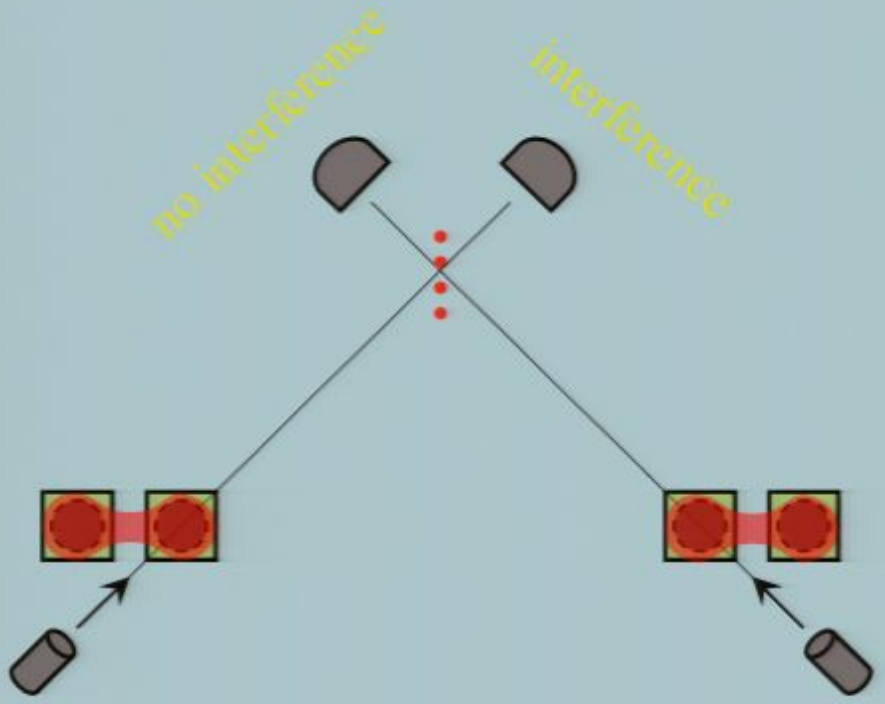

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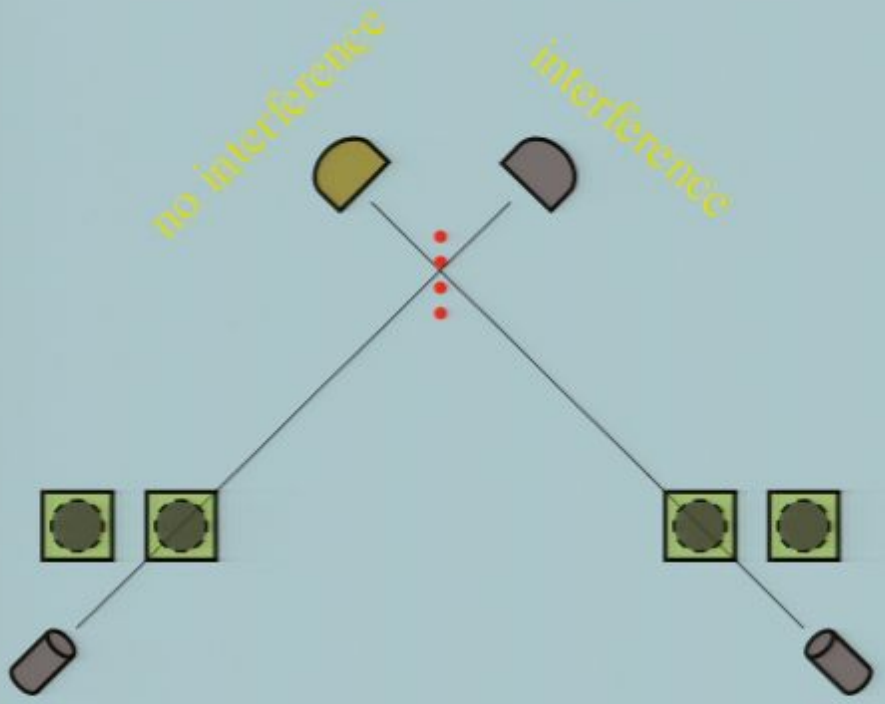

$$\frac{1}{2}\left(\left|x_1 \uparrow\right\rangle + i\left|x_1 \downarrow\right\rangle\right)\left(\left|x_2 \downarrow\right\rangle + i\left|x_2 \uparrow\right\rangle\right)$$

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3. Where did the photon come from? **Ignorance begets entanglement!**

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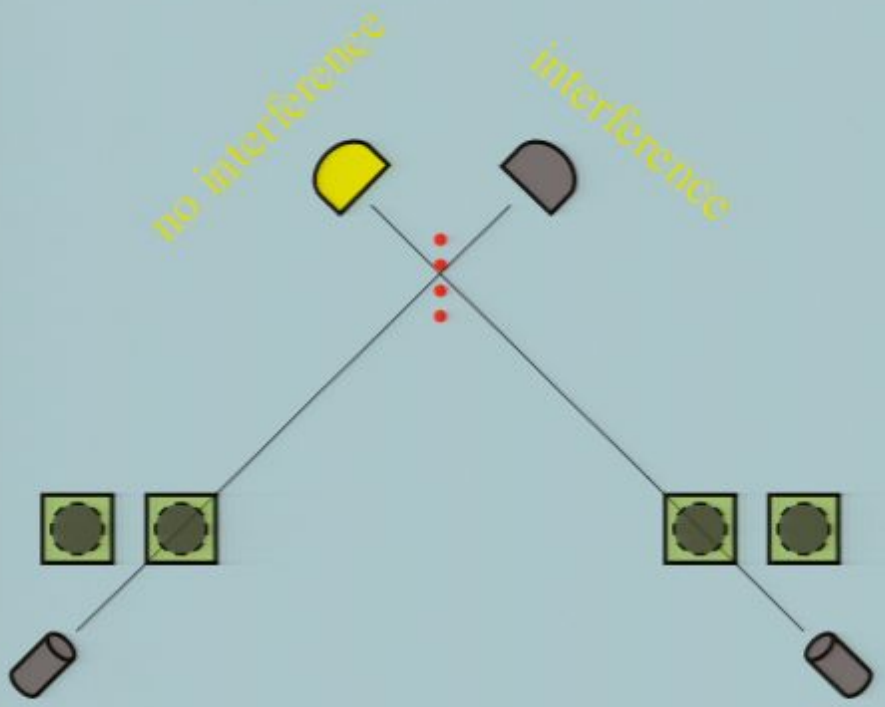

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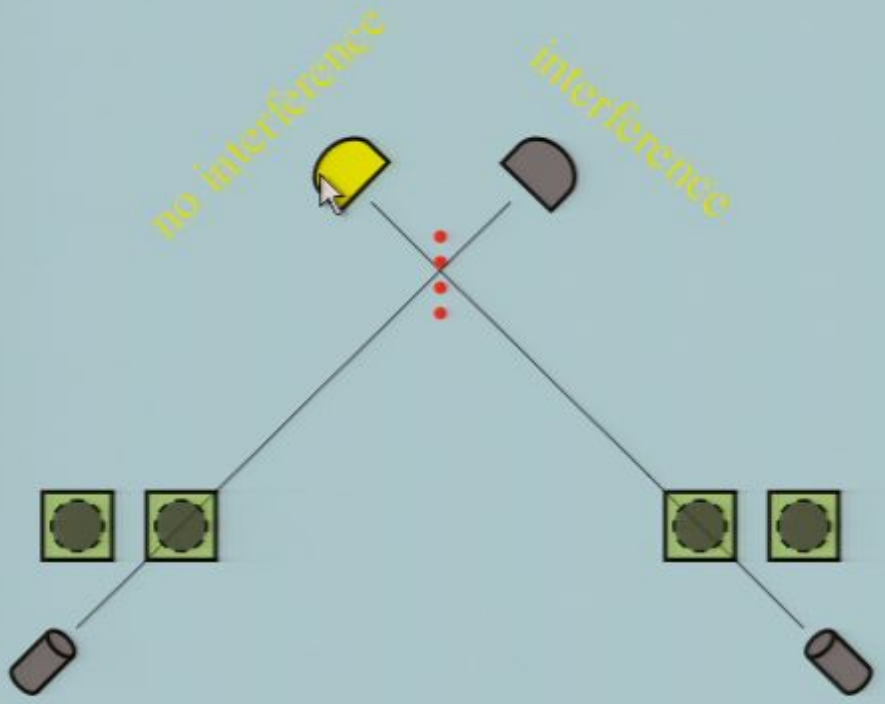

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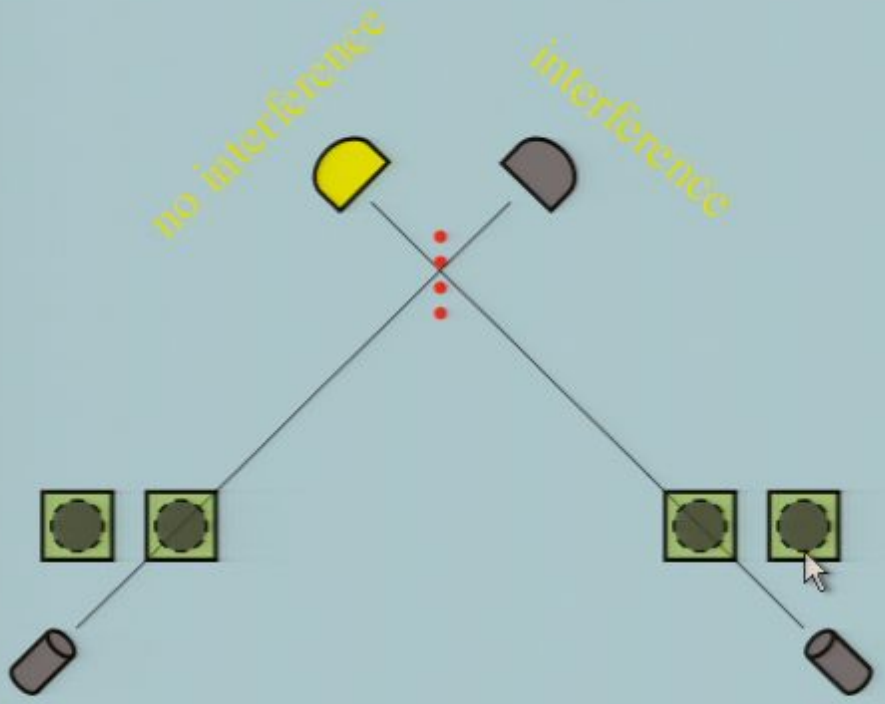

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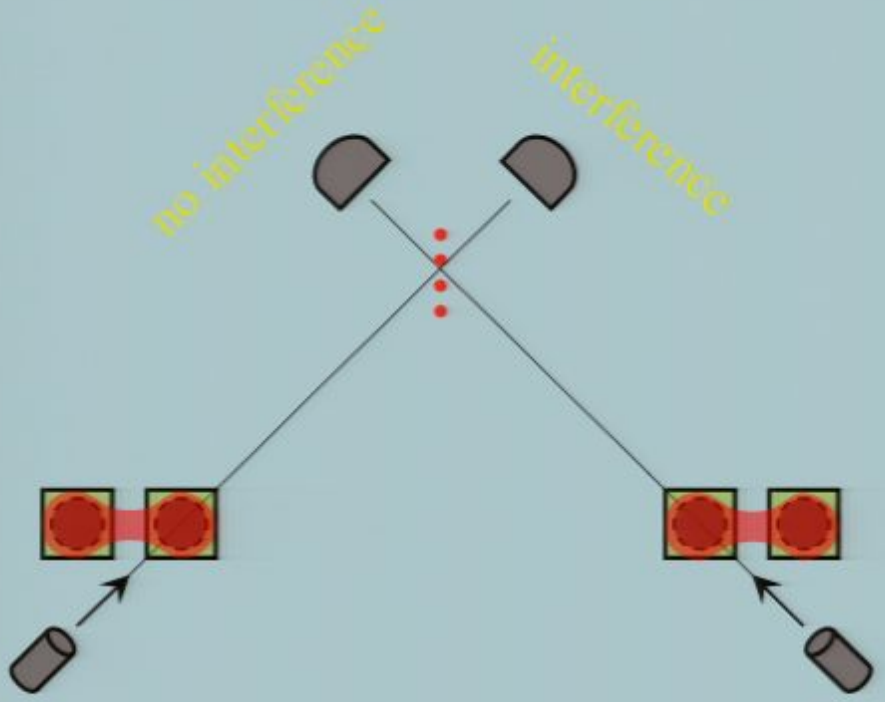

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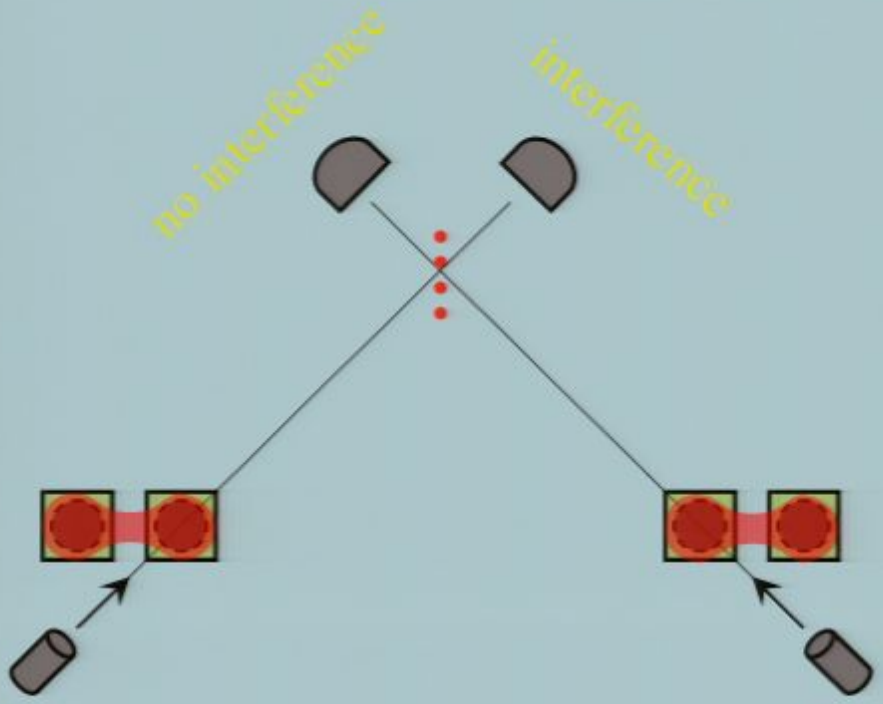

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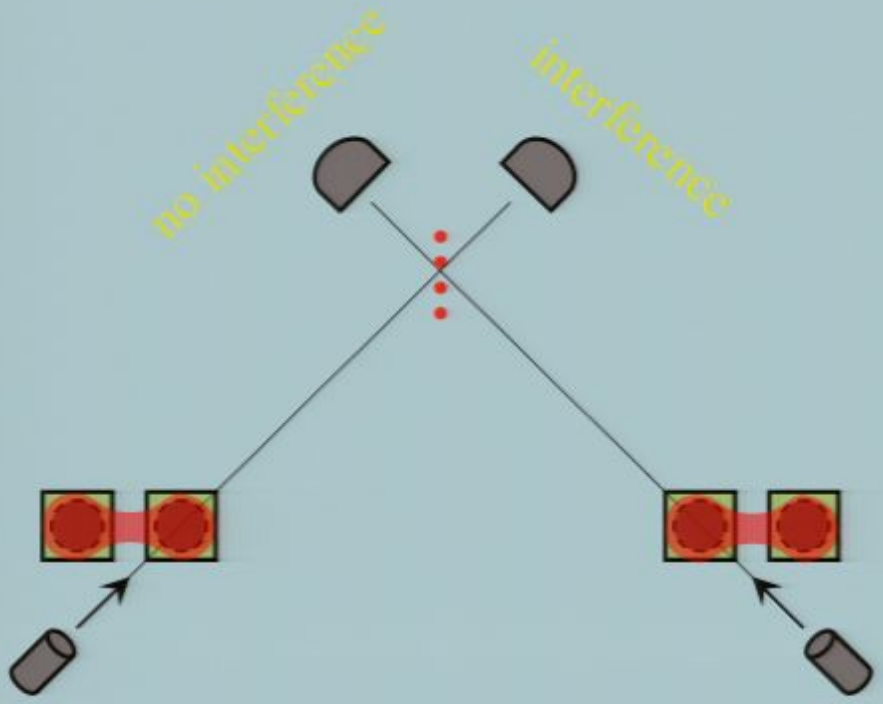

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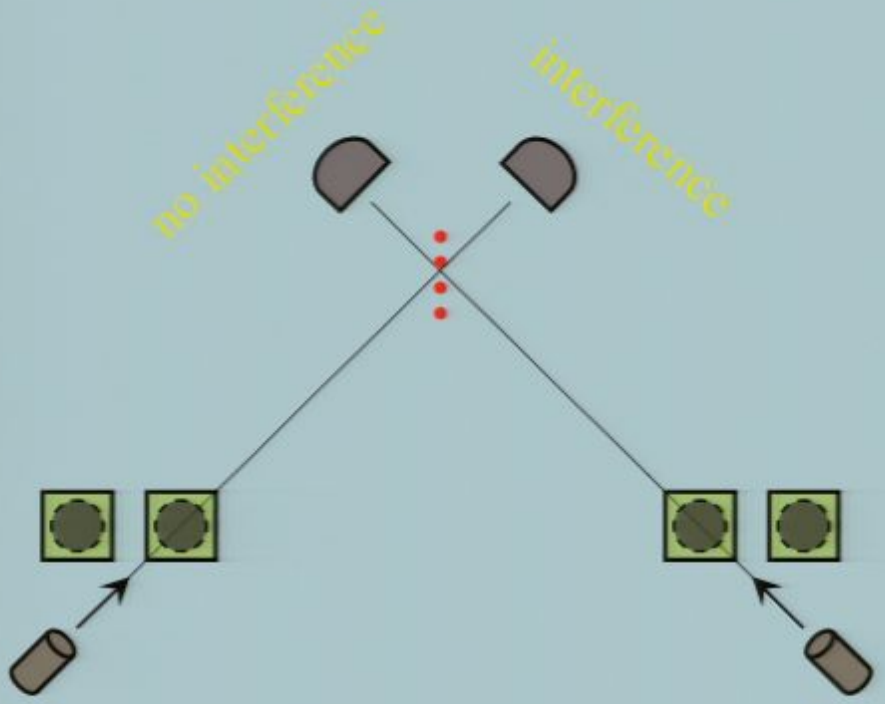

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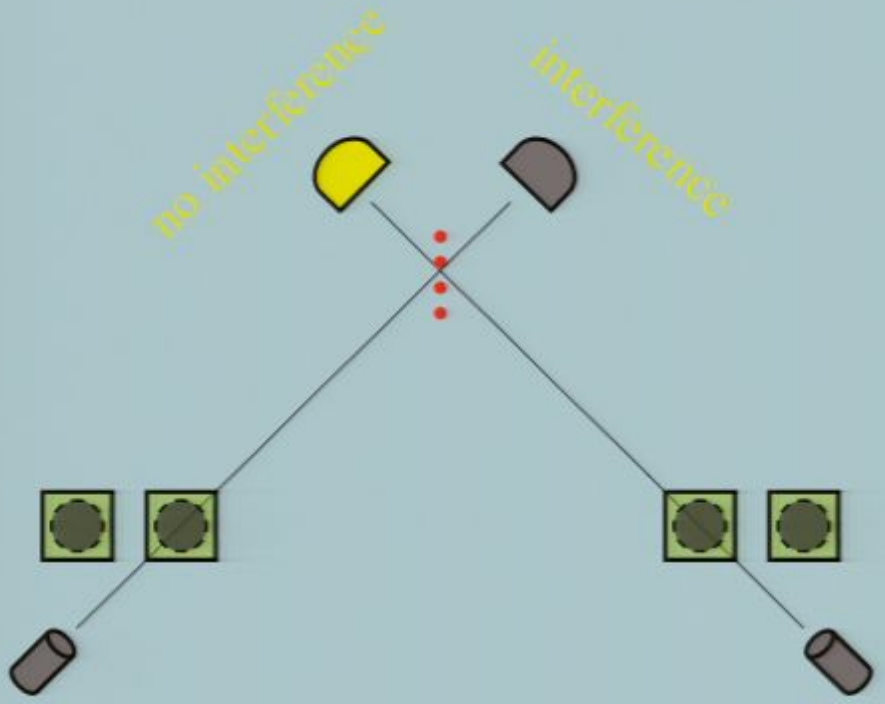

$$\frac{1}{\sqrt{2}}\left(|x_1 \uparrow\rangle|x_2 \downarrow\rangle - |x_1 \downarrow\rangle|x_2 \uparrow\rangle\right)$$

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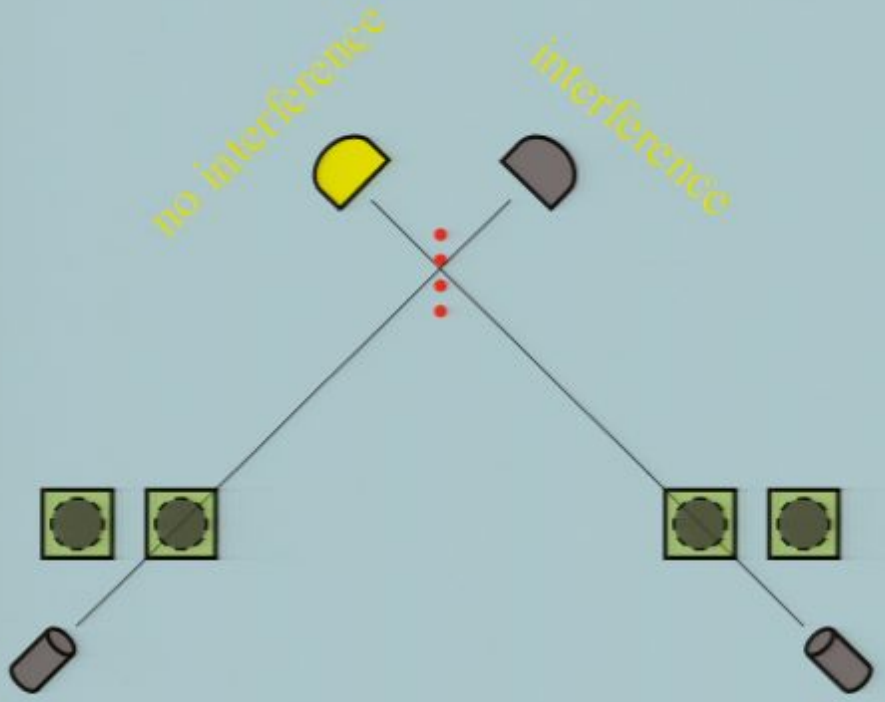

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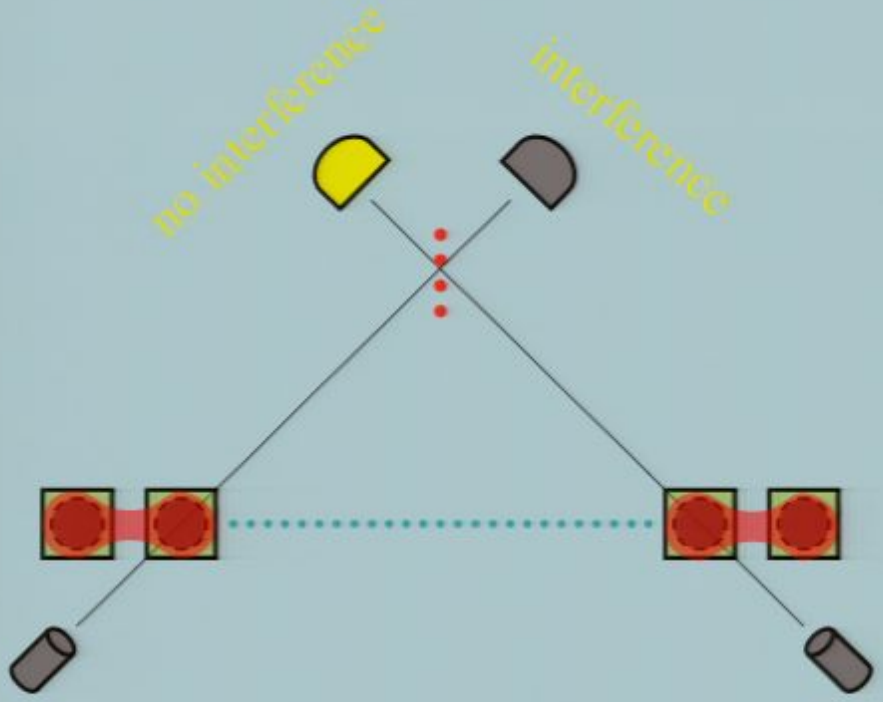

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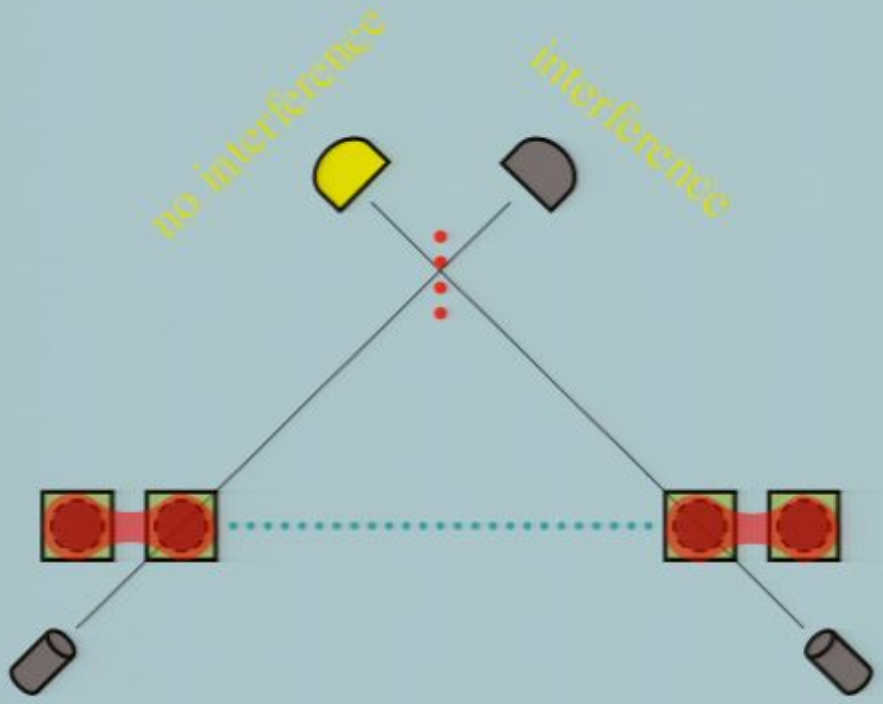

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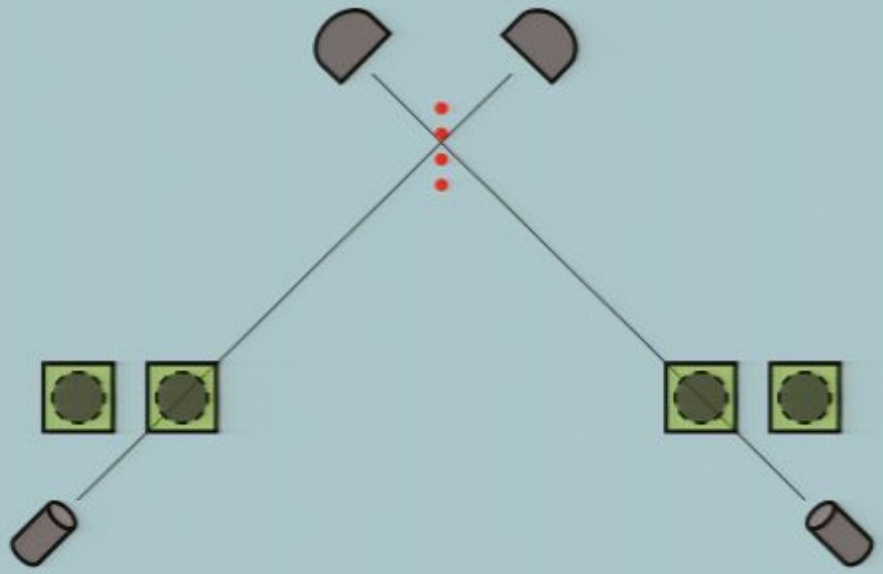
... or better call it: ***RPE***

The Bell Inequality Violations

The results predicted by QM:

Measured Directions		Correlation
0^0	0^0	100%
30^0	30^0	100%
…		
0^0	-30^0	75%
30^0	0^0	75%
…		
-30^0	30^0	**25% !**
30^0	-30^0	**25% !**

The Quantum Liar Paradox



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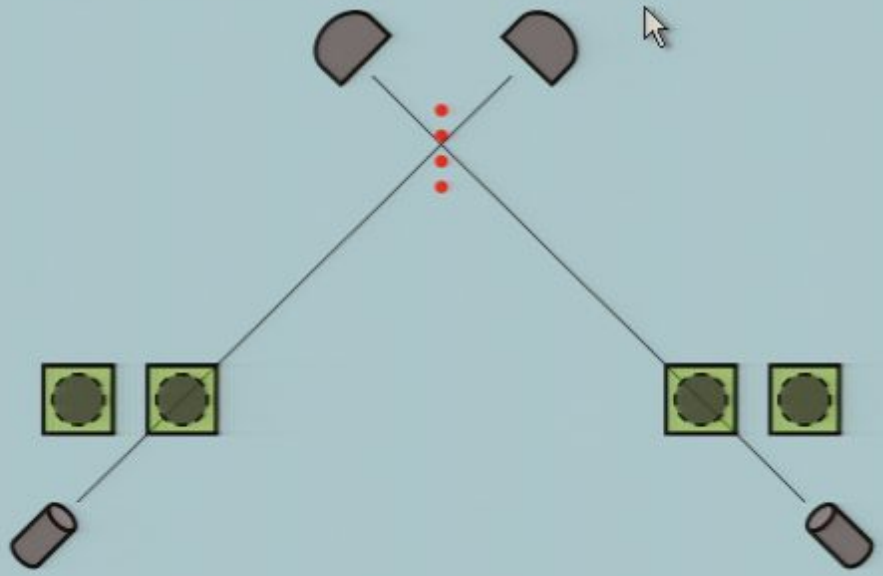
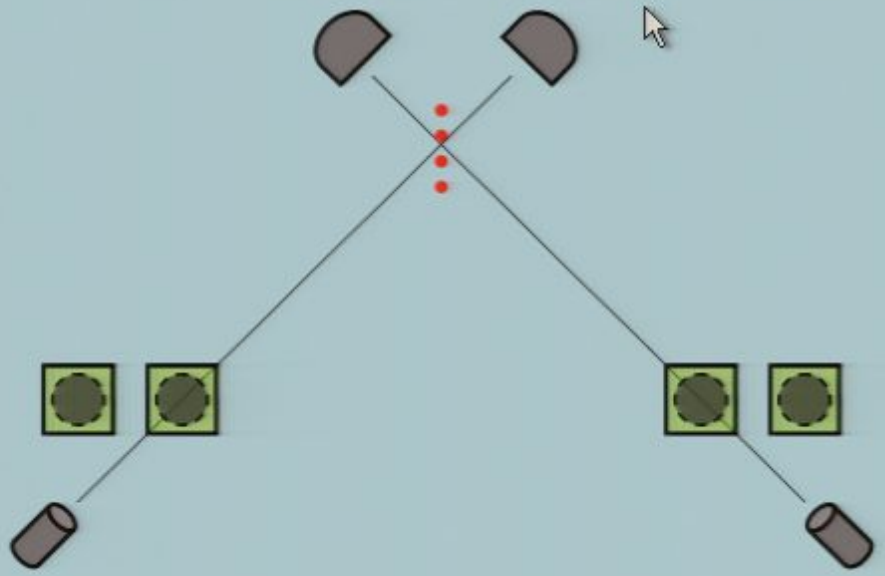


- To prove non-locality, test the two Hardy atoms for Bell Inequality

The Quantum Liar Paradox



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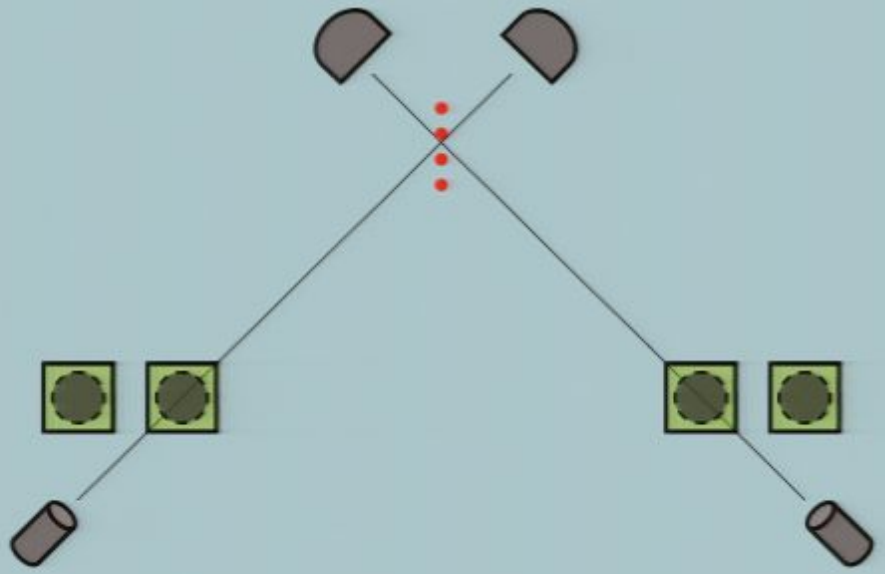

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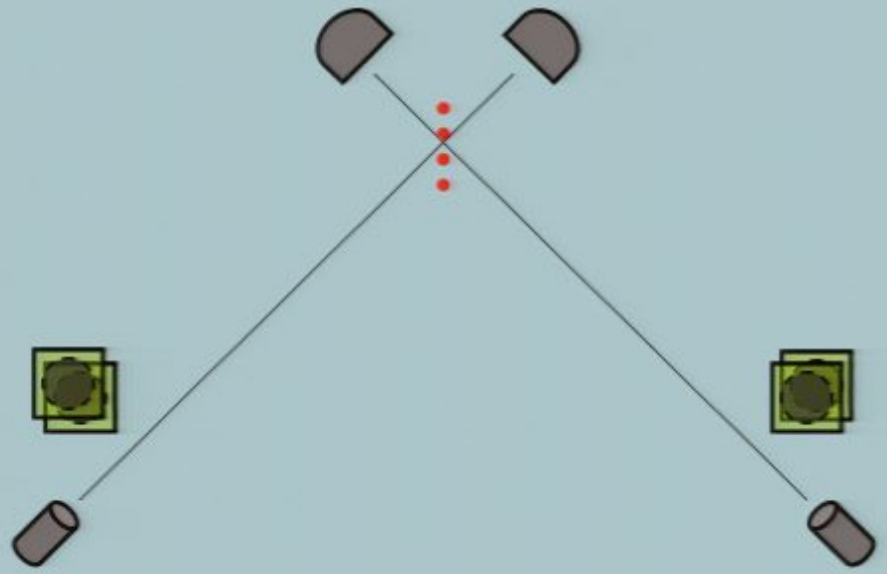

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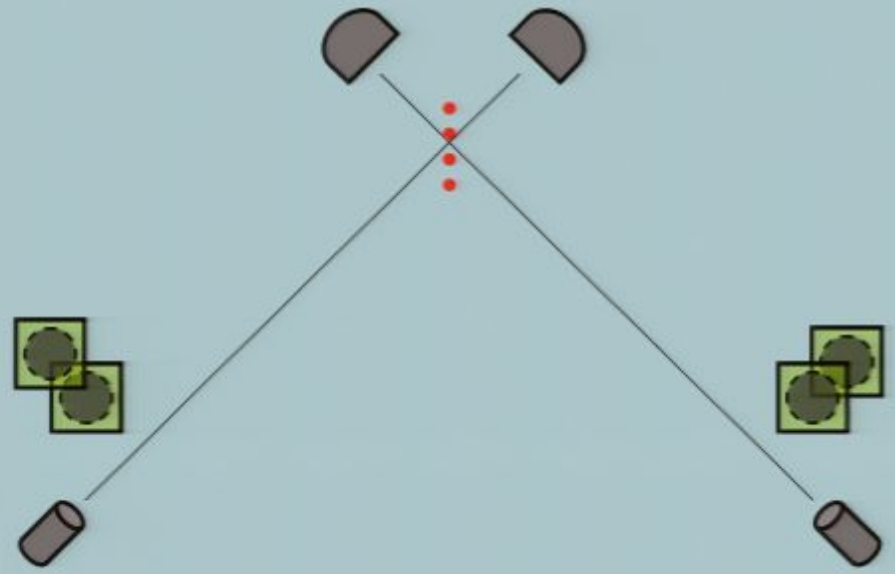

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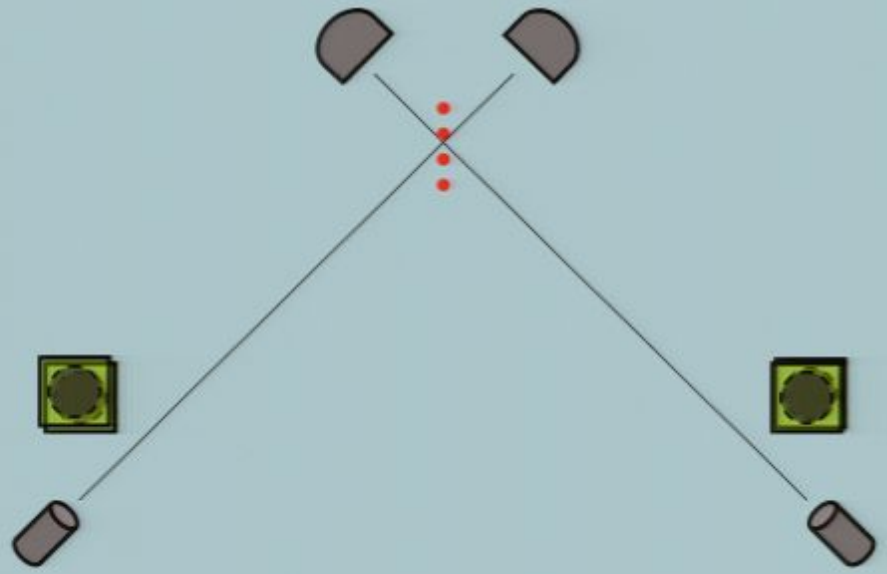

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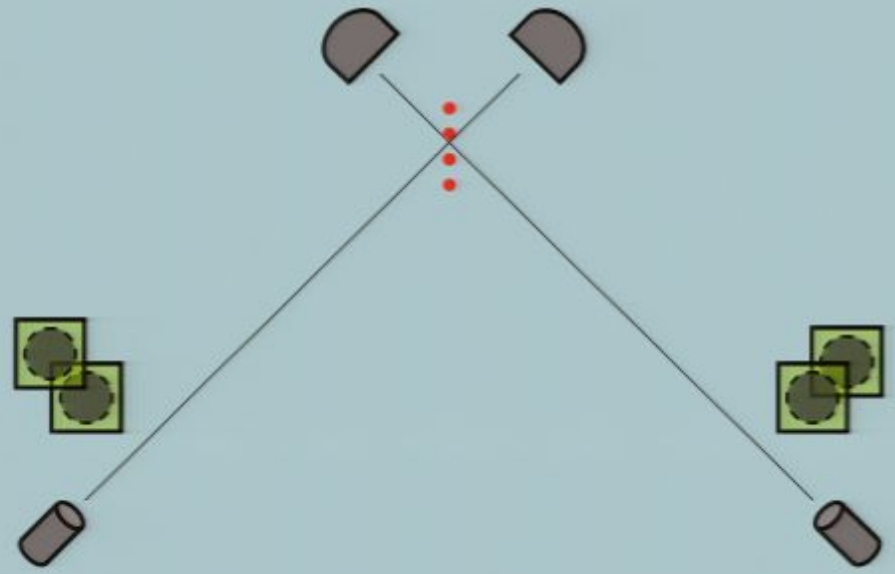

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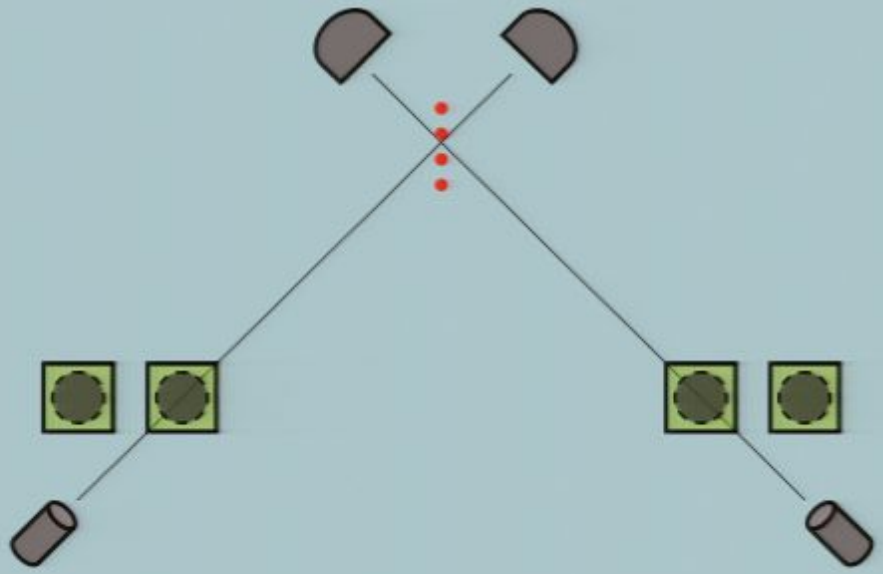

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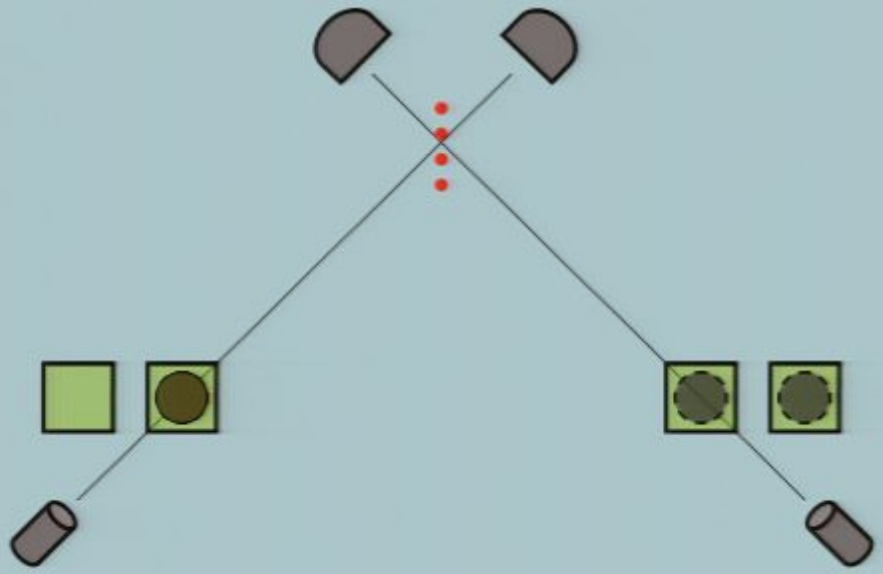
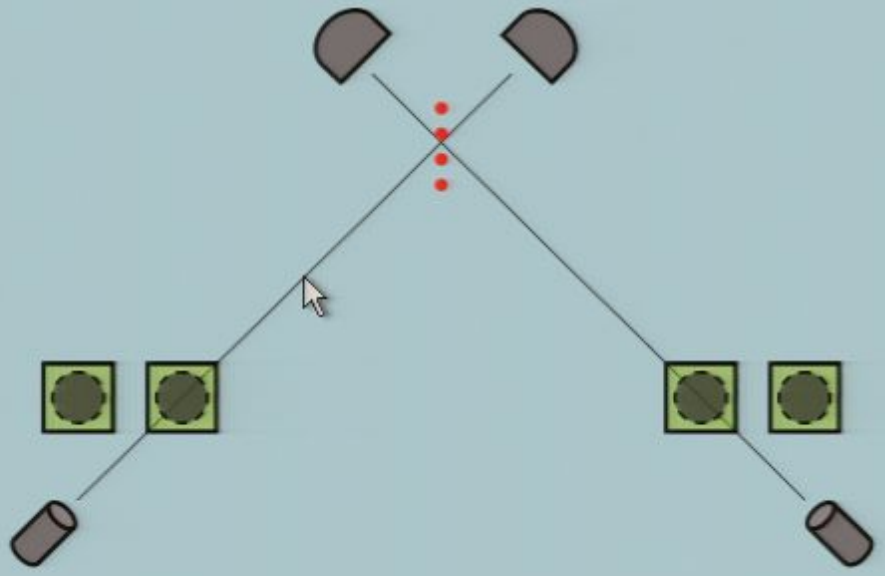


- 0^0 direction ("which box") measurement allows only one history for the photon

The Quantum Liar Paradox



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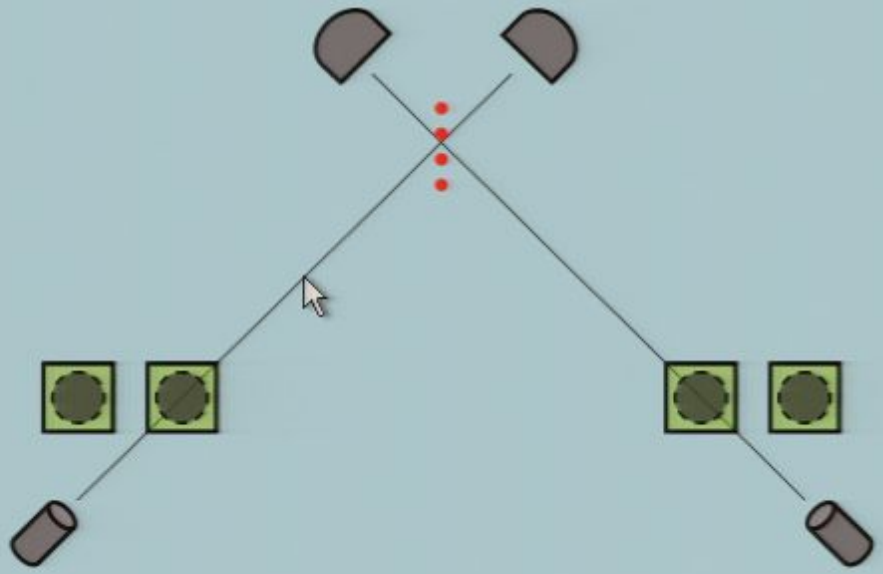

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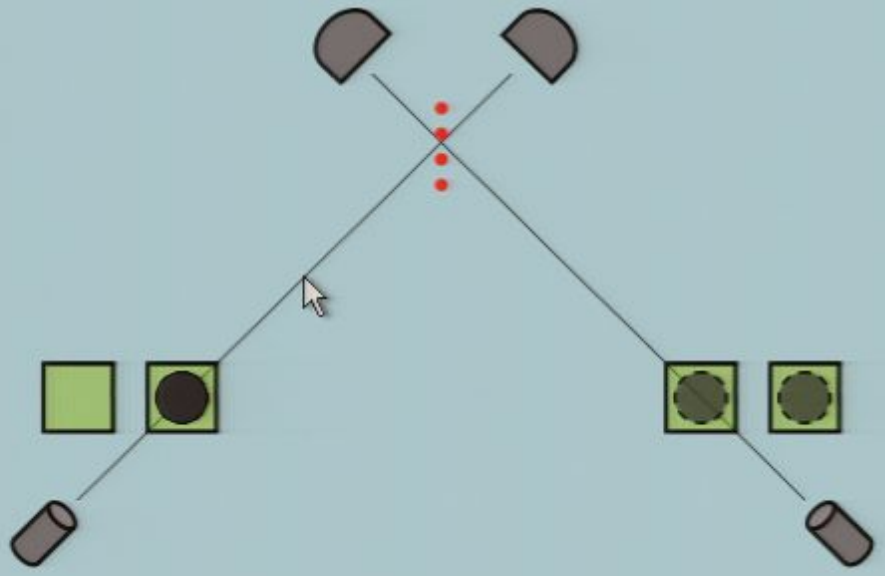

- 0^0 direction ("which box") measurement on the left atom

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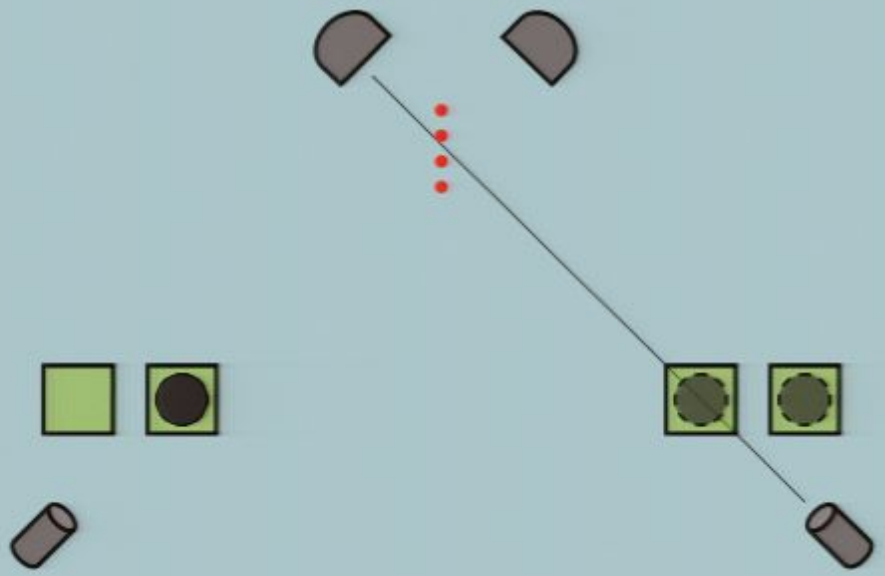

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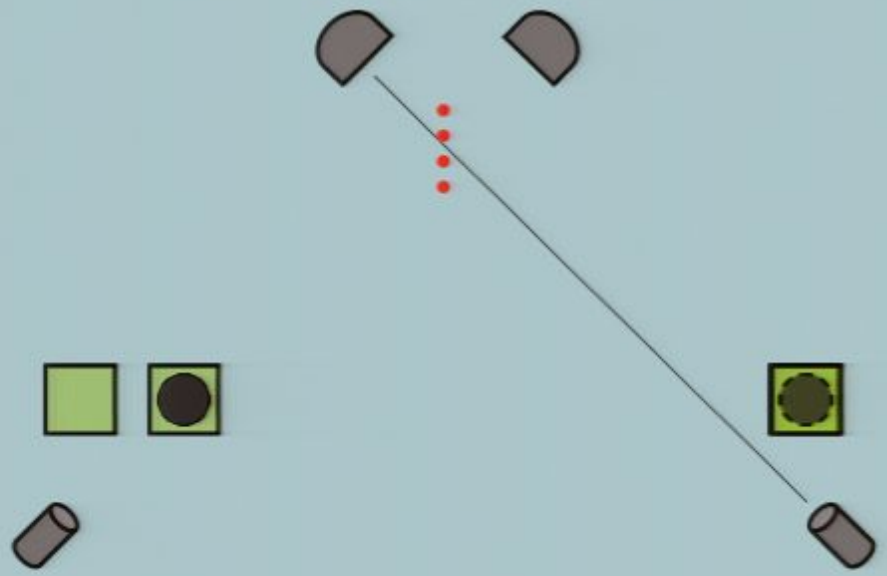
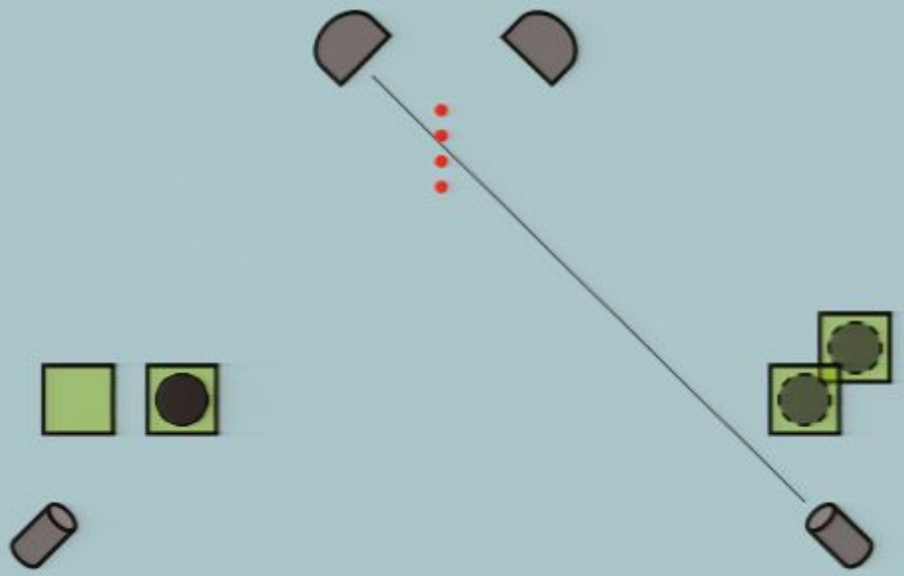


- 0^0 direction ("which box") measurement on the left atom
- But a different direction (30^0, -30^0) measurement on the right atom

The Quantum Liar Paradox



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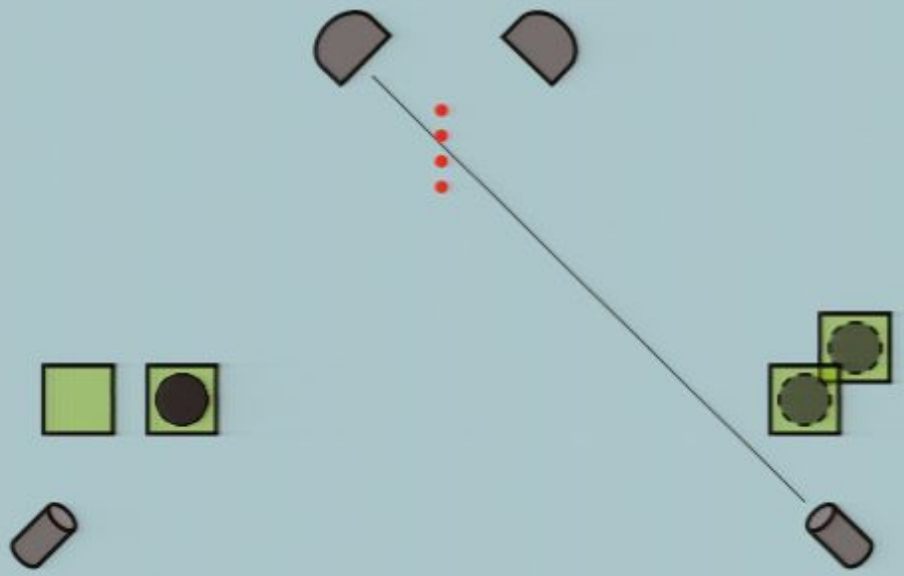

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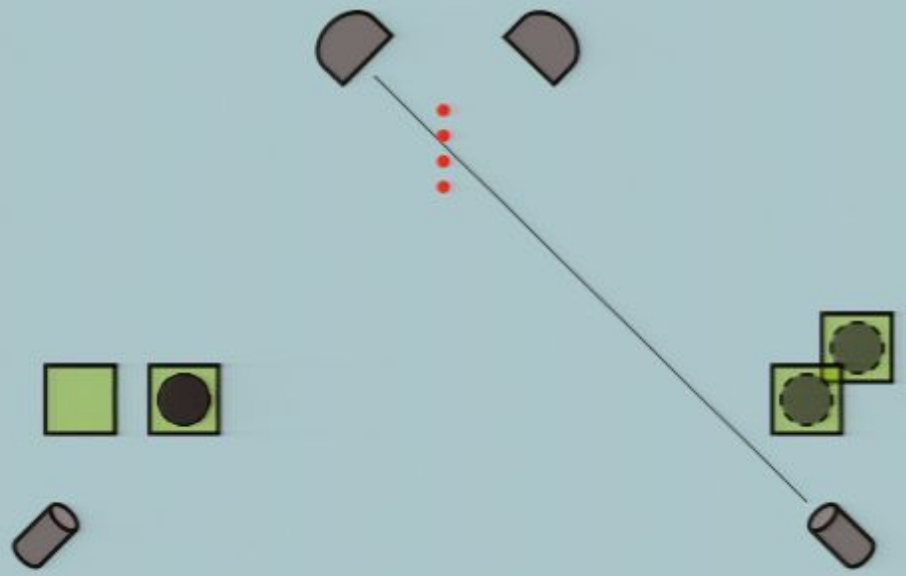

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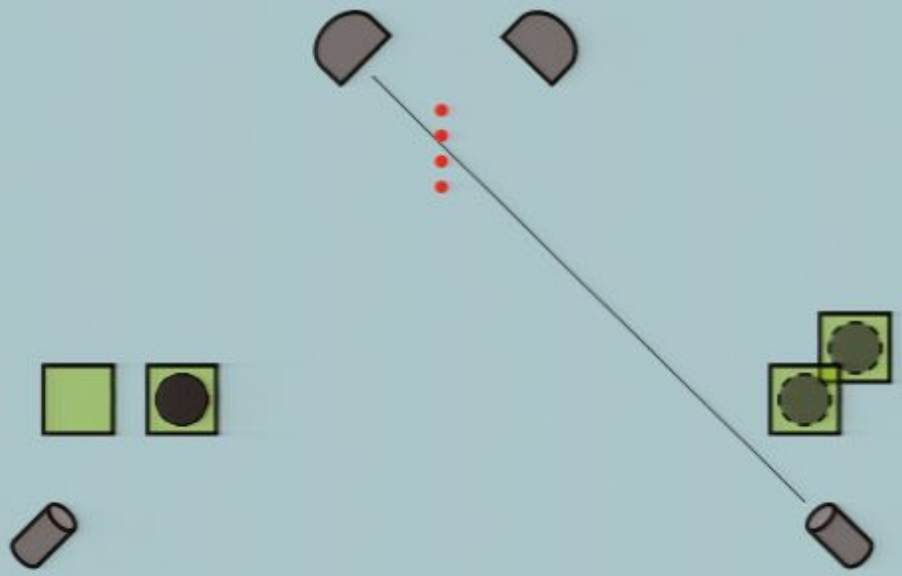
The Quantum Liar Paradox



- 0^0 direction ("which box") measurement on the left atom
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- Here too, there are Bell Inequality violations...
- Which require a non-local effect between the left and the right atoms!

The Quantum Liar Paradox

So, you end up with the following history:

The Quantum Liar Paradox

So, you end up with the following history:

- One atom is found to have blocked the photon's path.

The Quantum Liar Paradox

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Which is logically equivalent to saying…

THIS SENTENCE HAS NEVER BEEN WRITTEN

:-)

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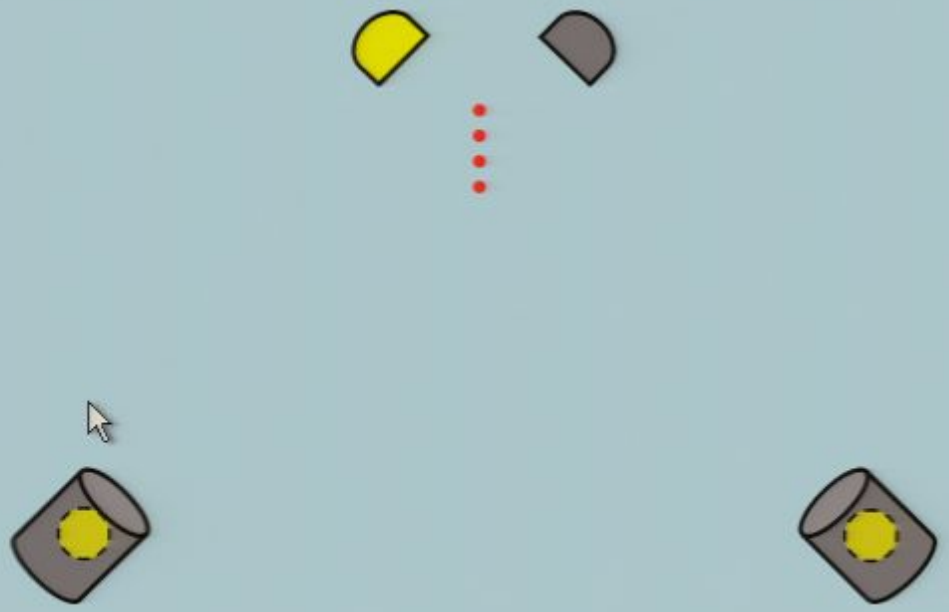

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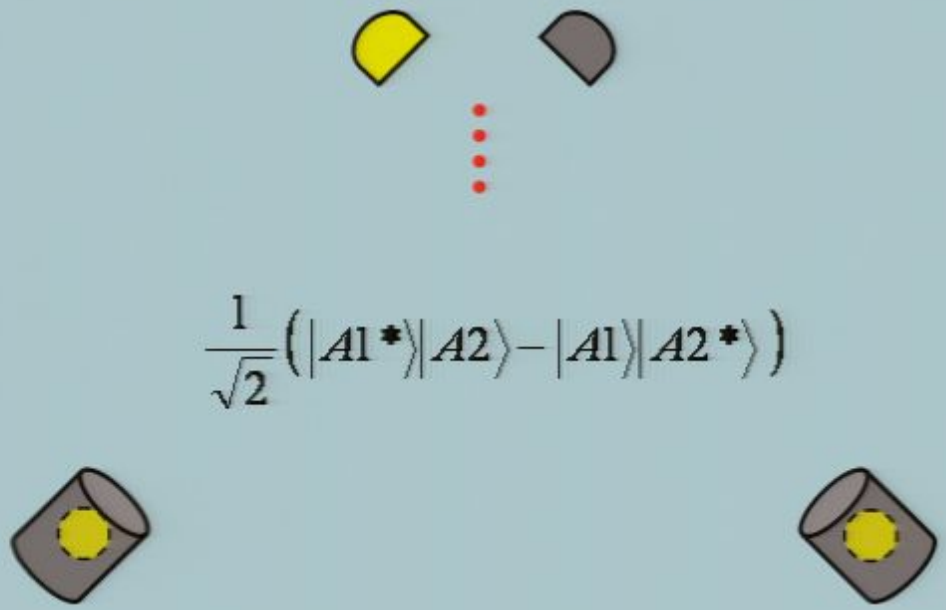

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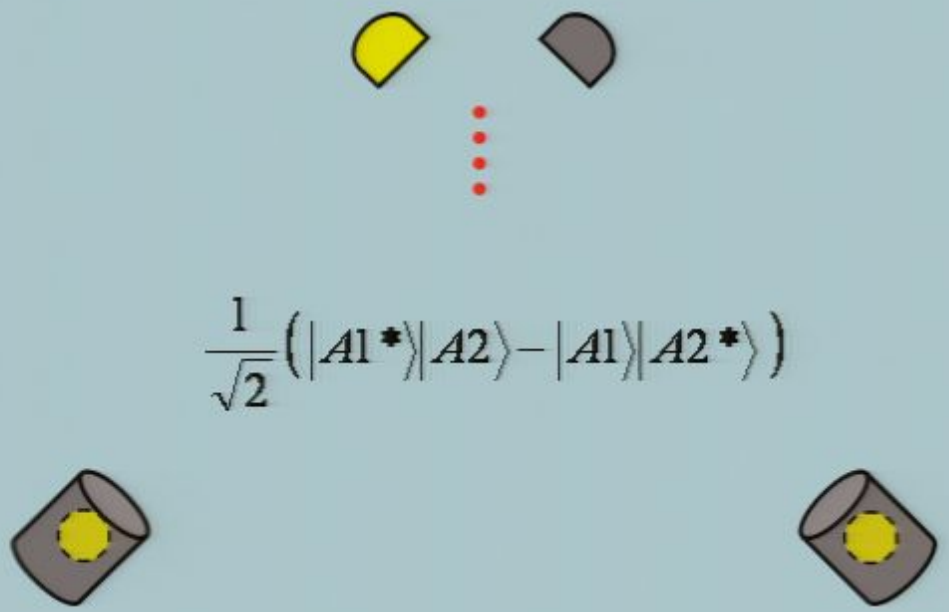

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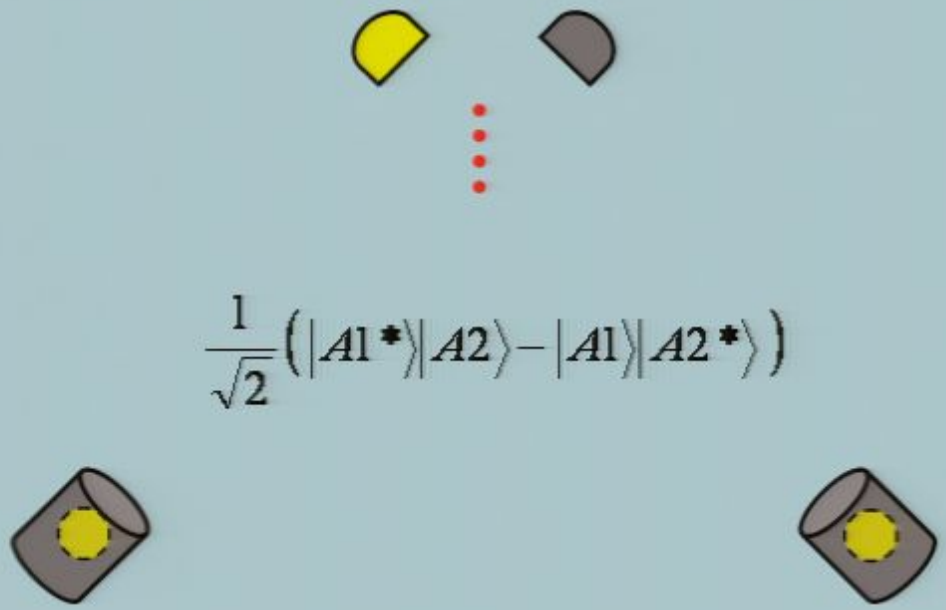

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- The liar paradox all over again

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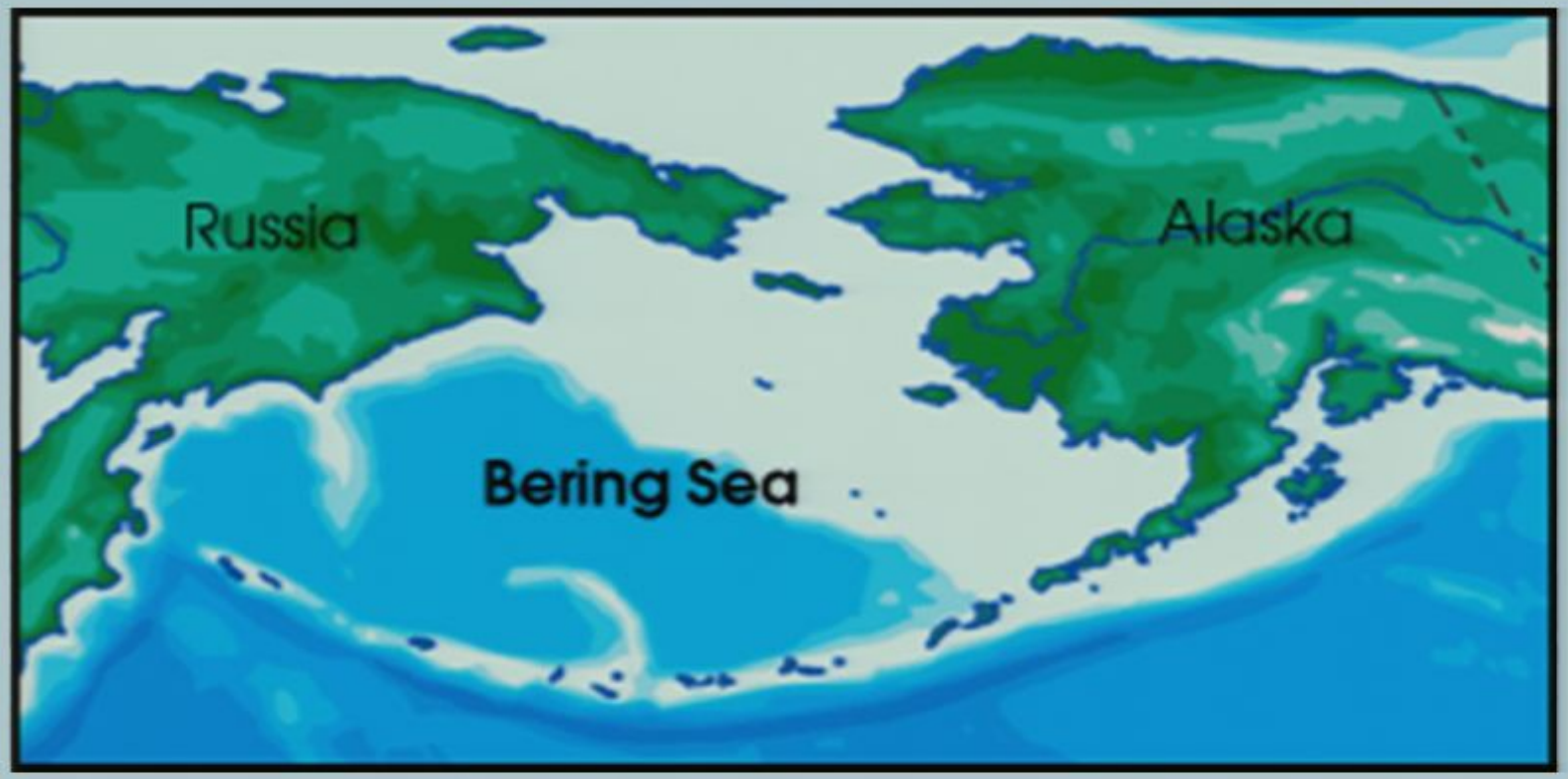
"Every quantum event is visited twice, once by the state vector coming from the pre-selection and then again by the vector coming backwards from the post-selection" (Aharonov, personal communication).

Большая Советская Энциклопедия



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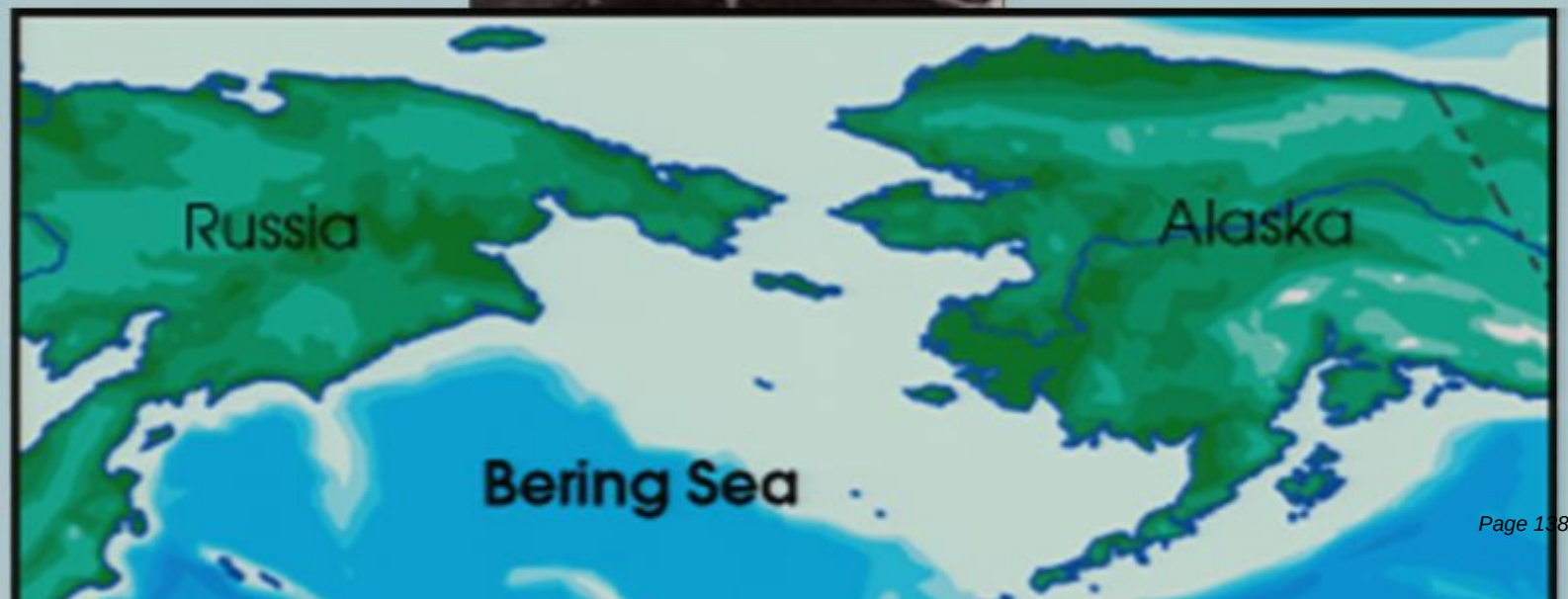

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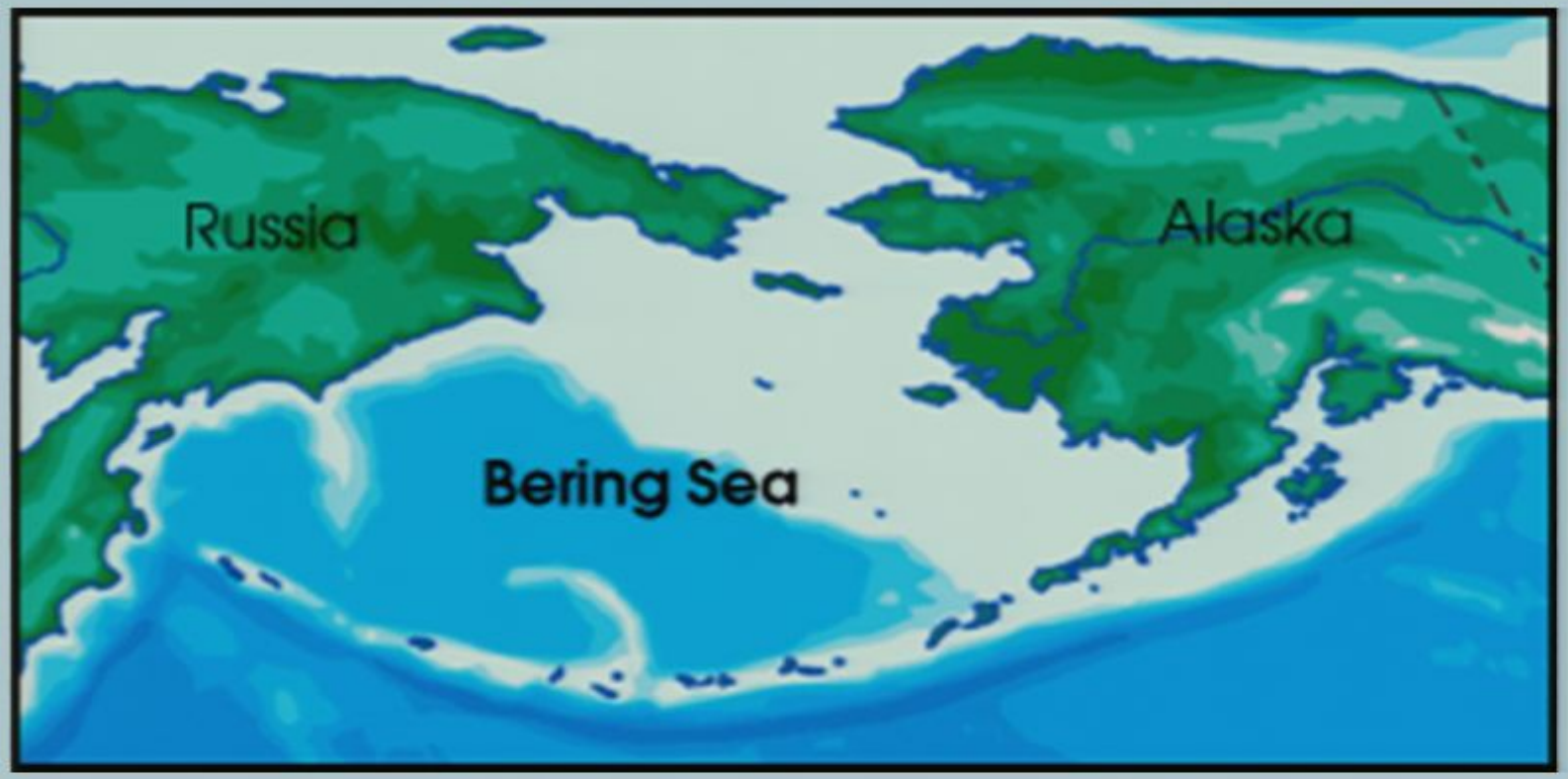

The Road Less Traveled

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."

Becoming – The Ultimate Compactification?

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It may make work just as well as extra space dimensions

The Machian Consequence

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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

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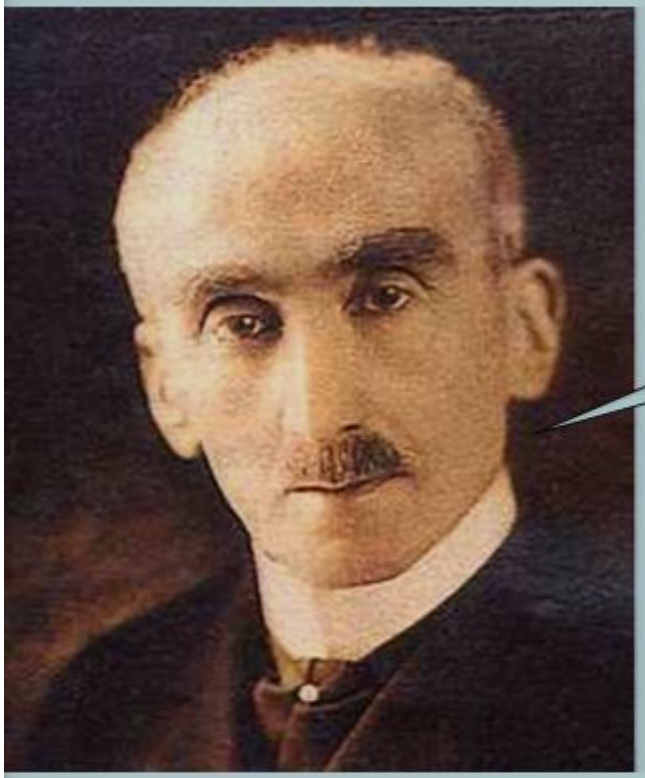
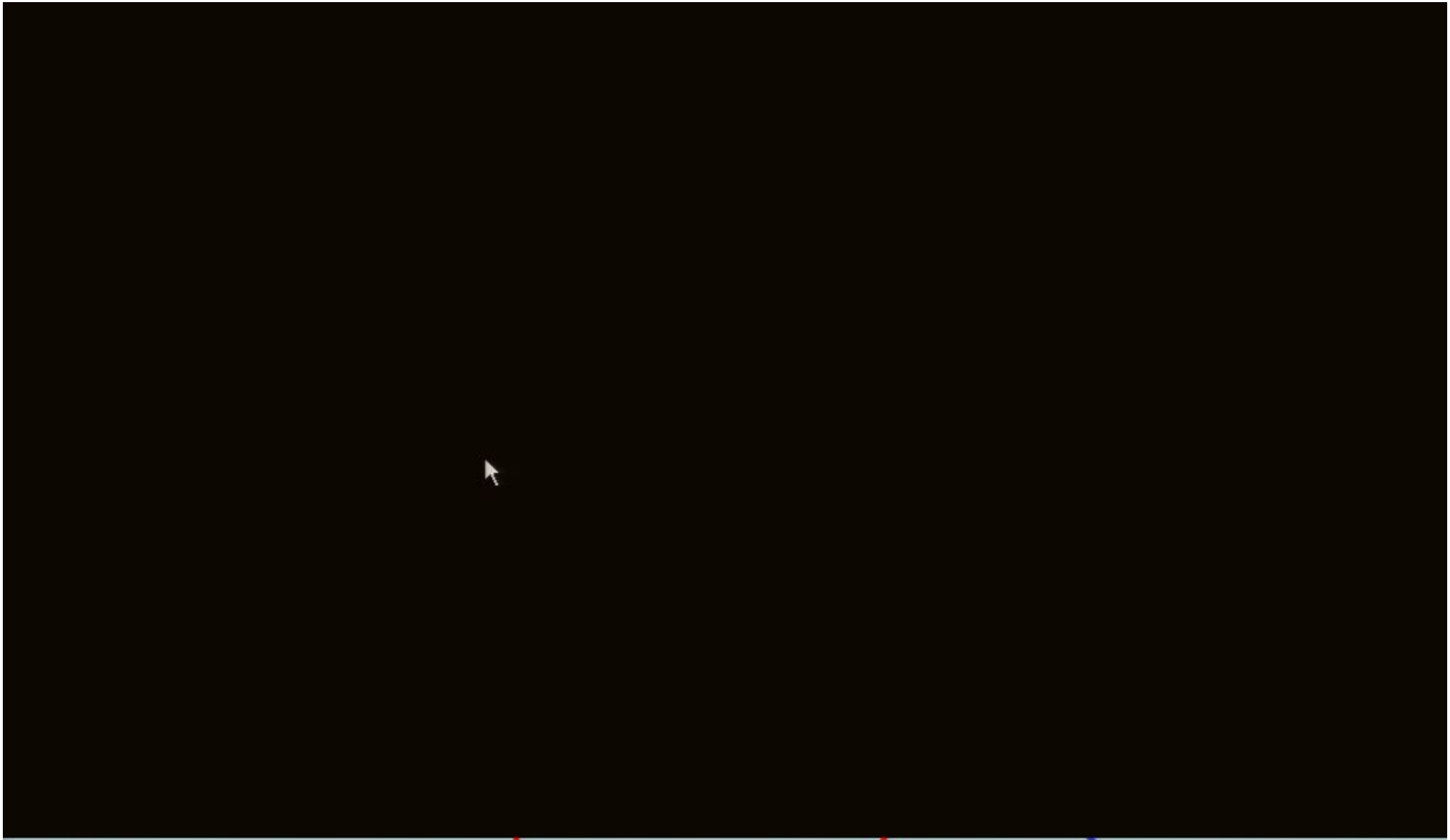
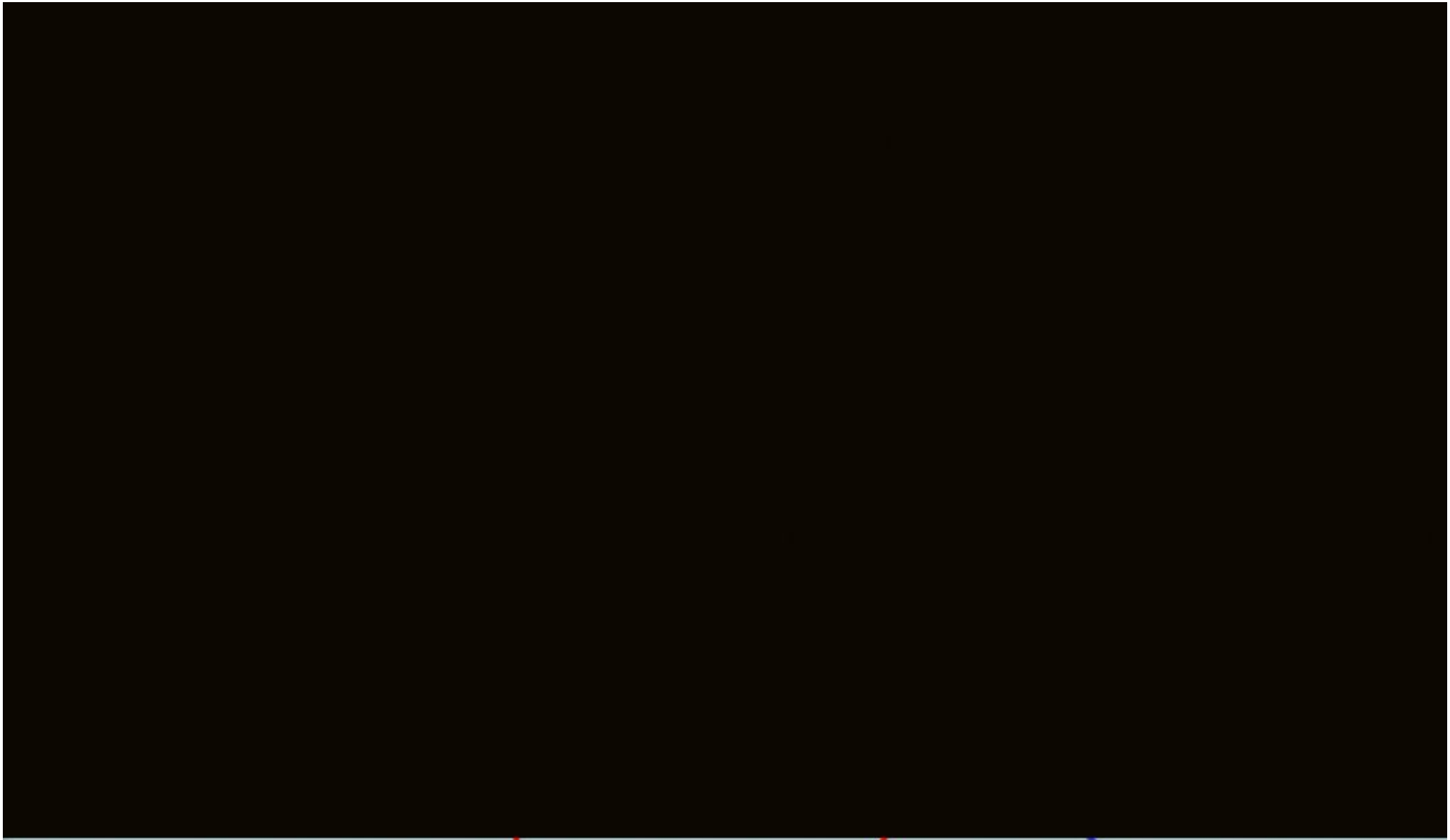


Never spatialize time!


Block Universe


Naïve Becoming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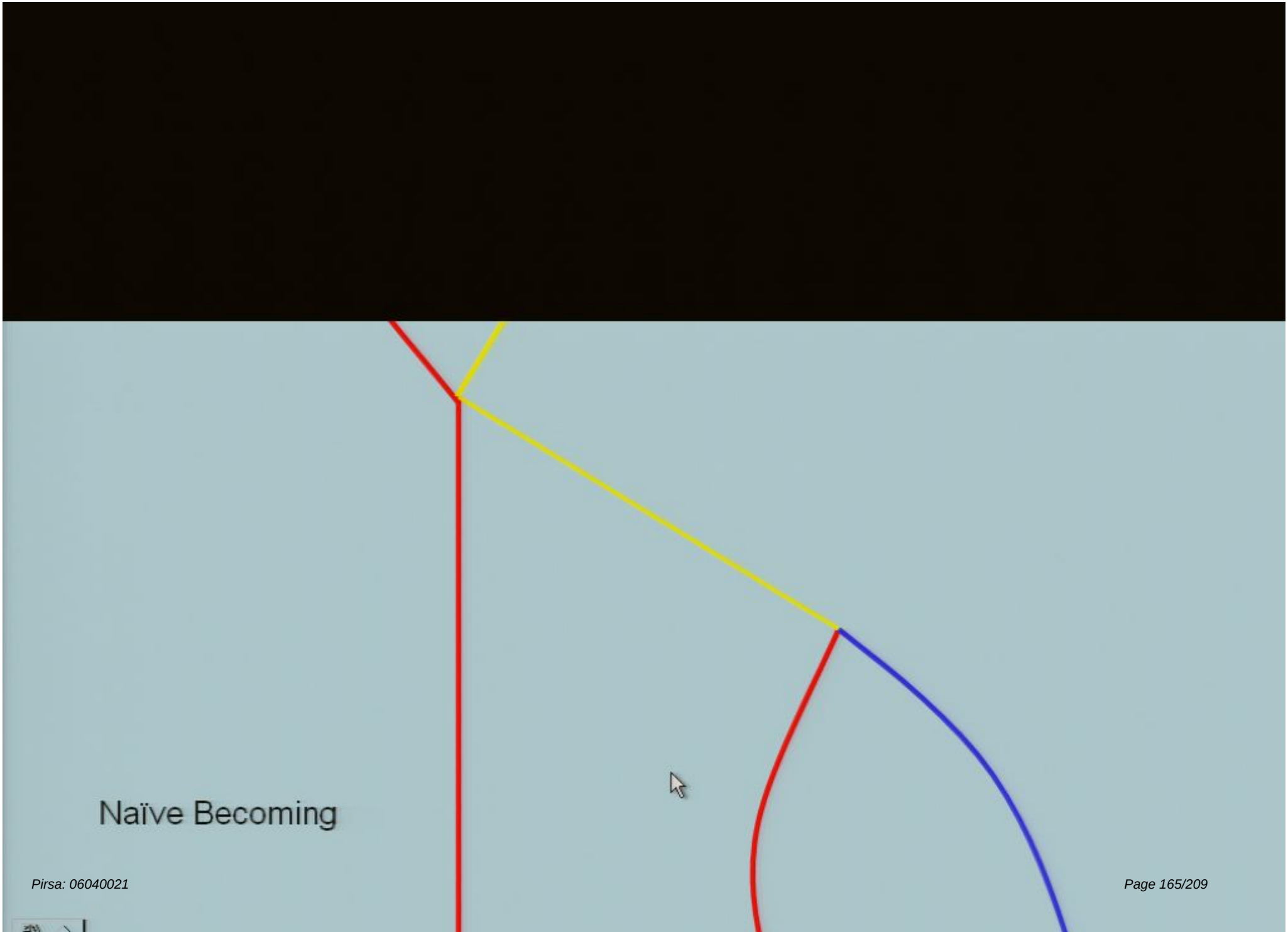
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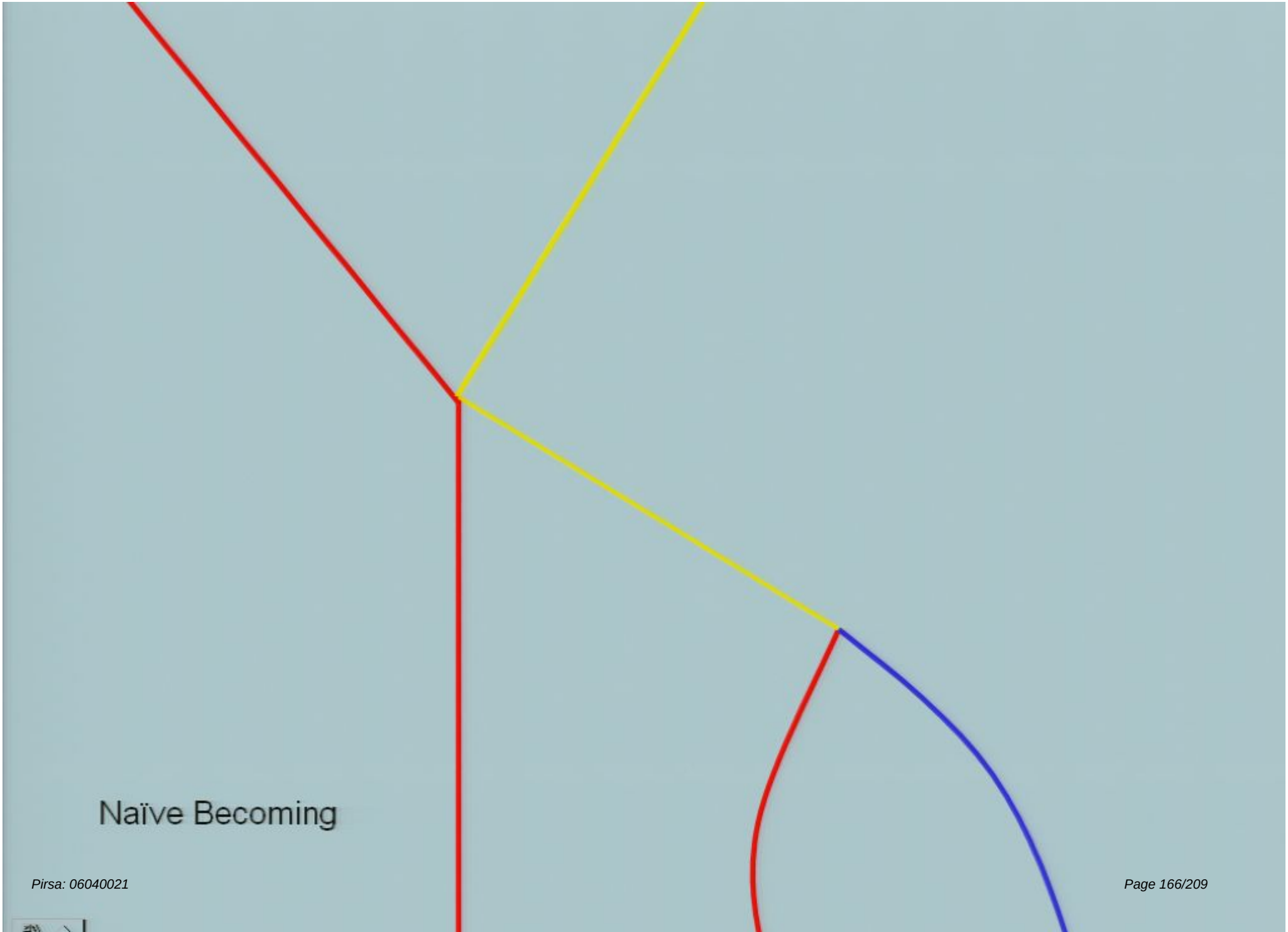
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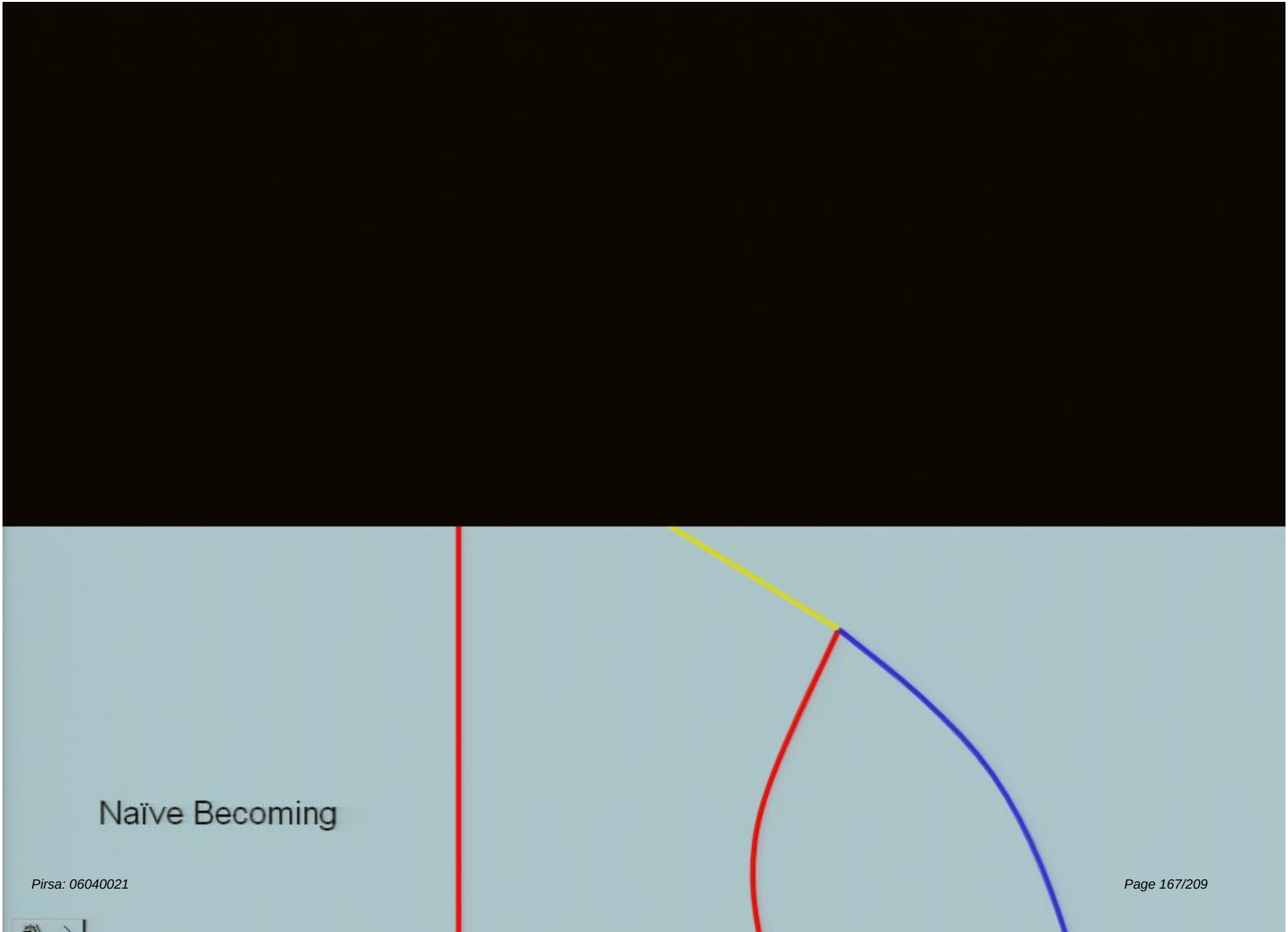
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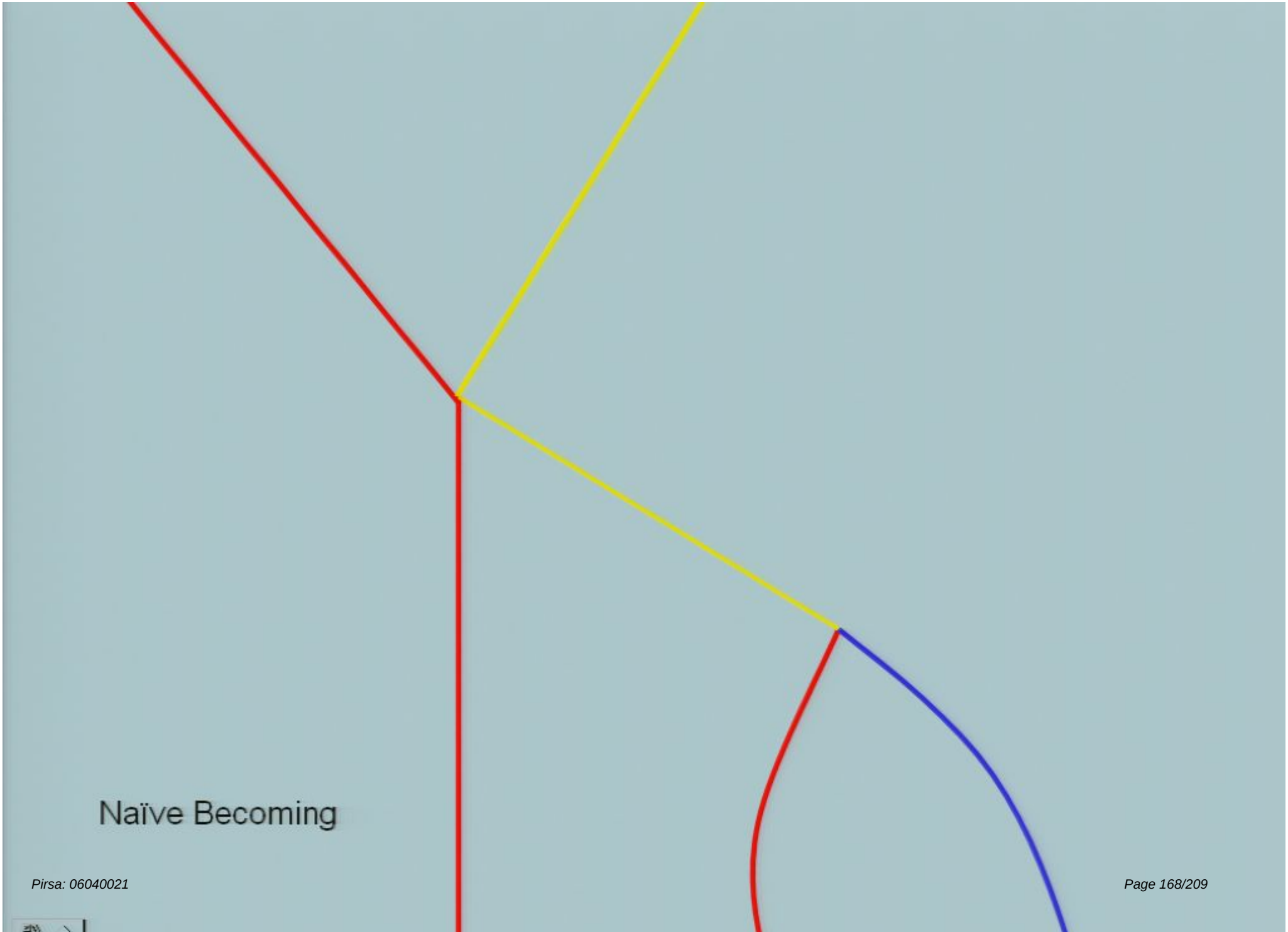
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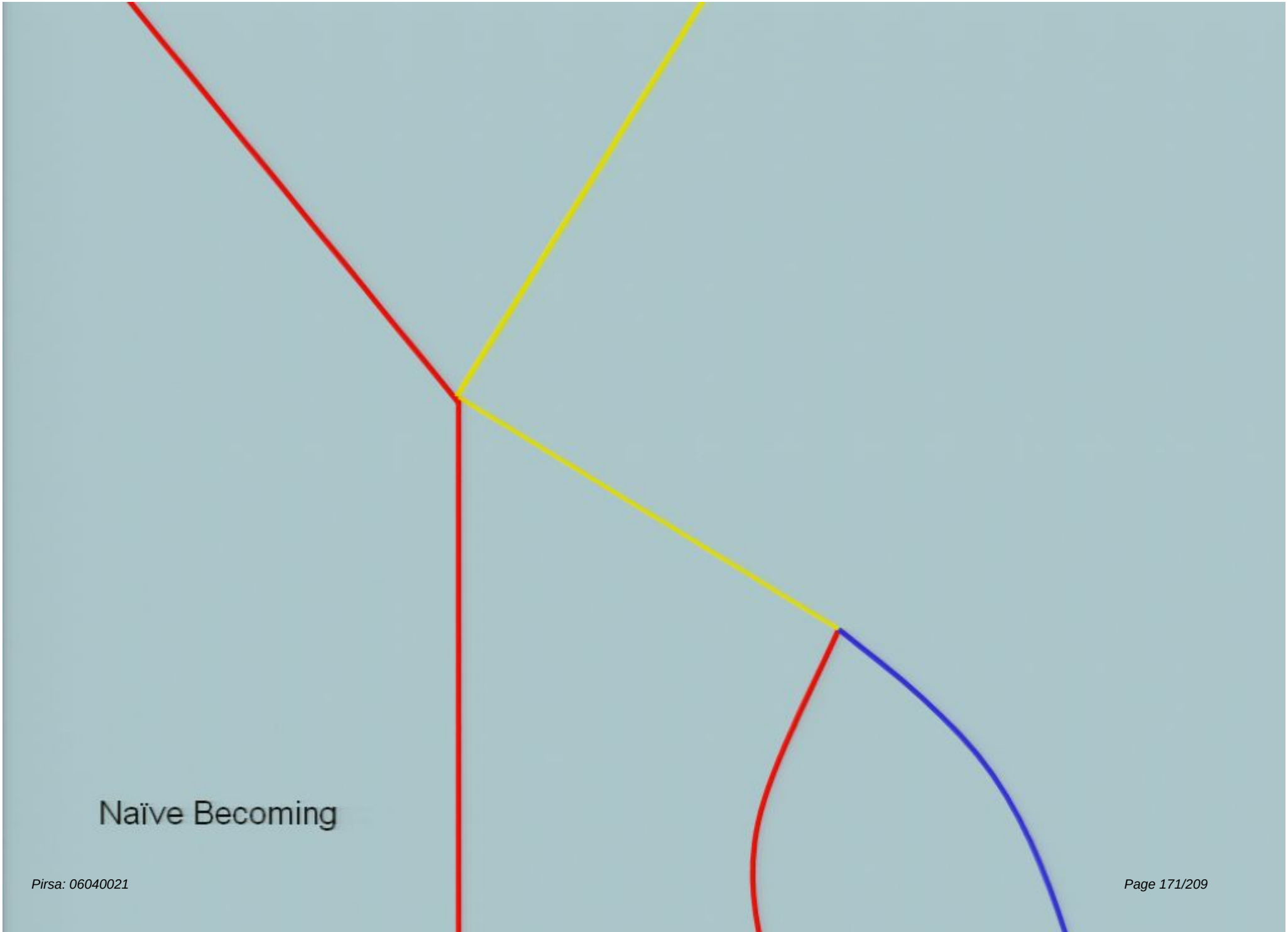
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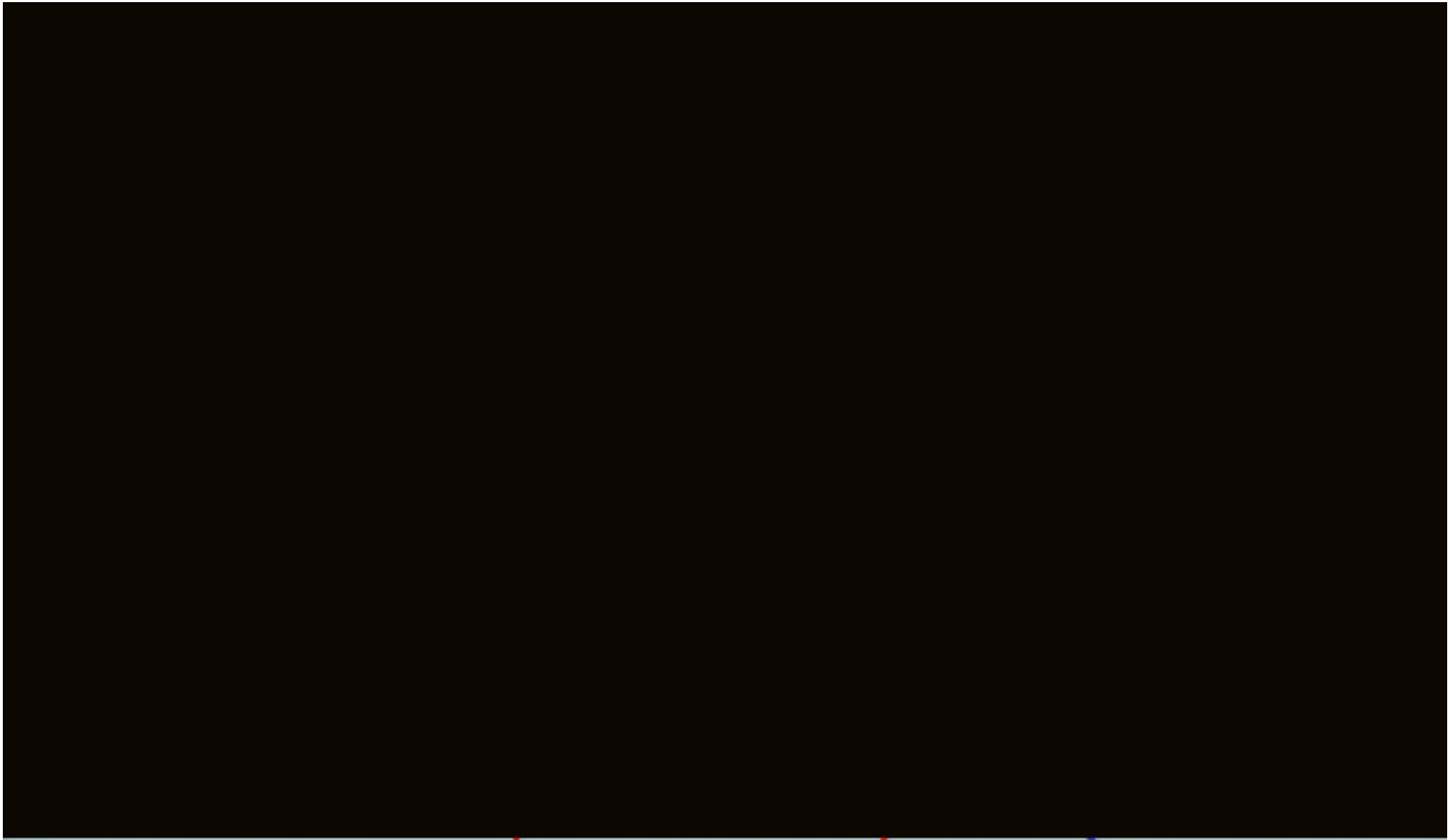
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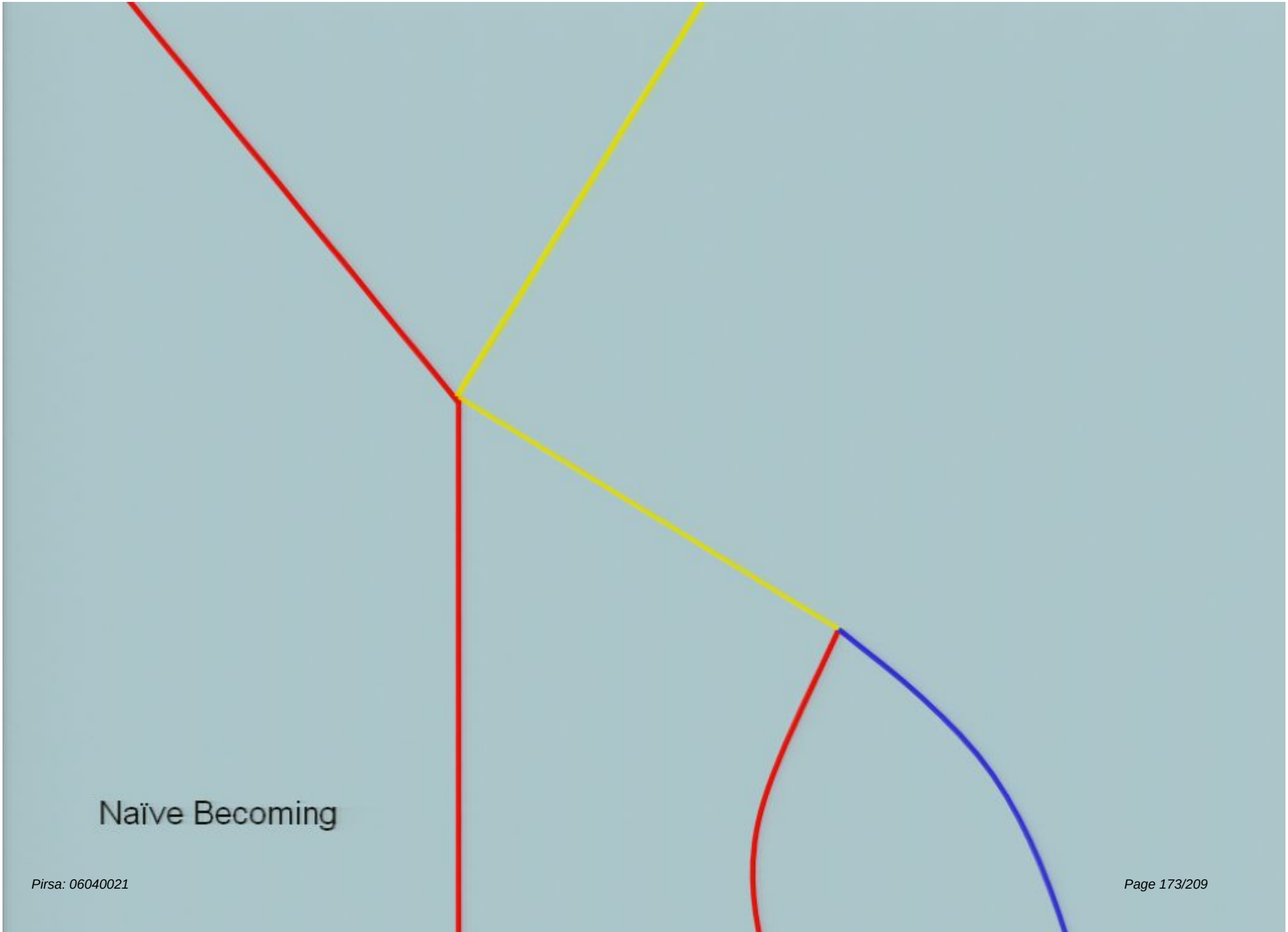
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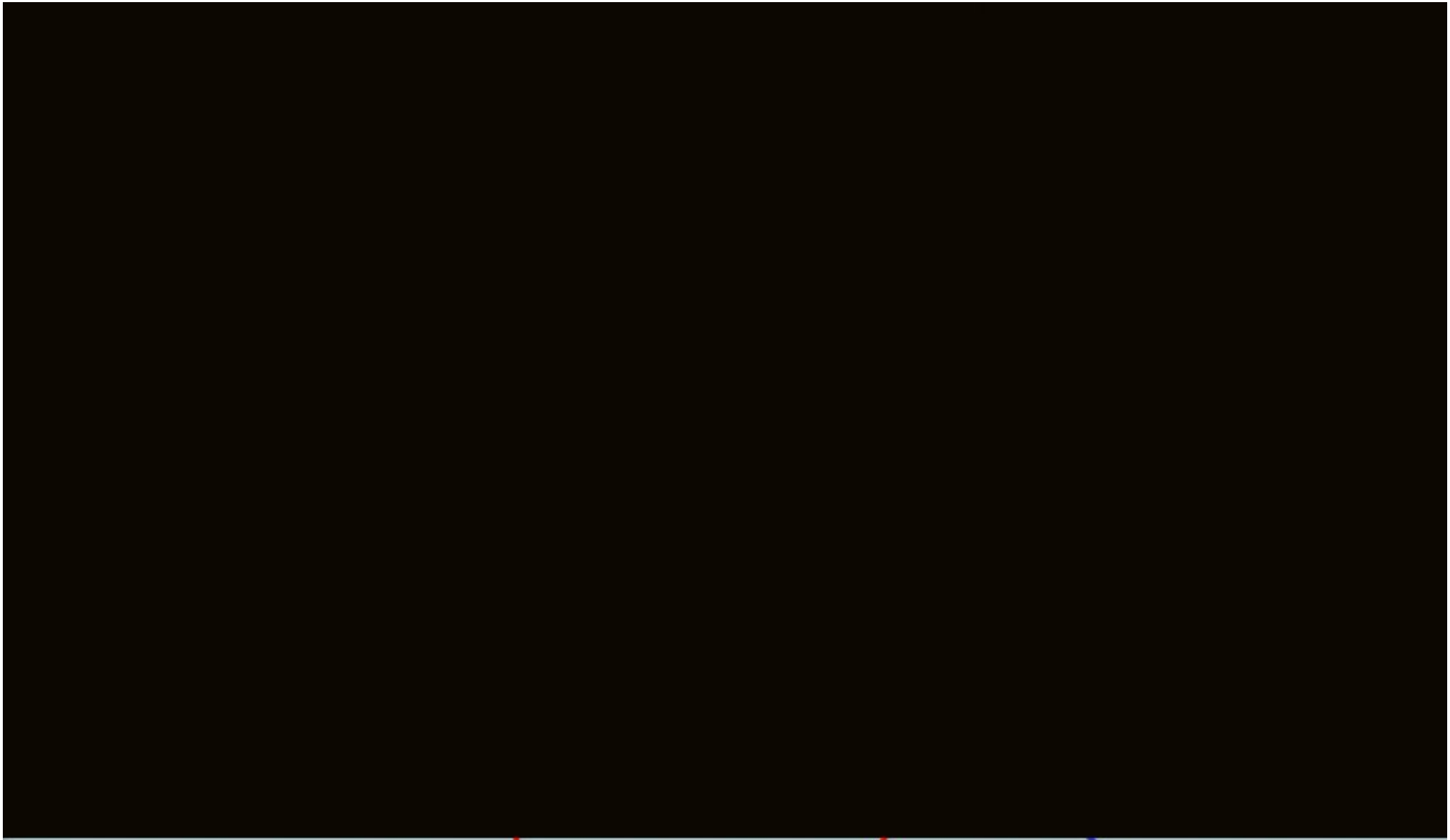
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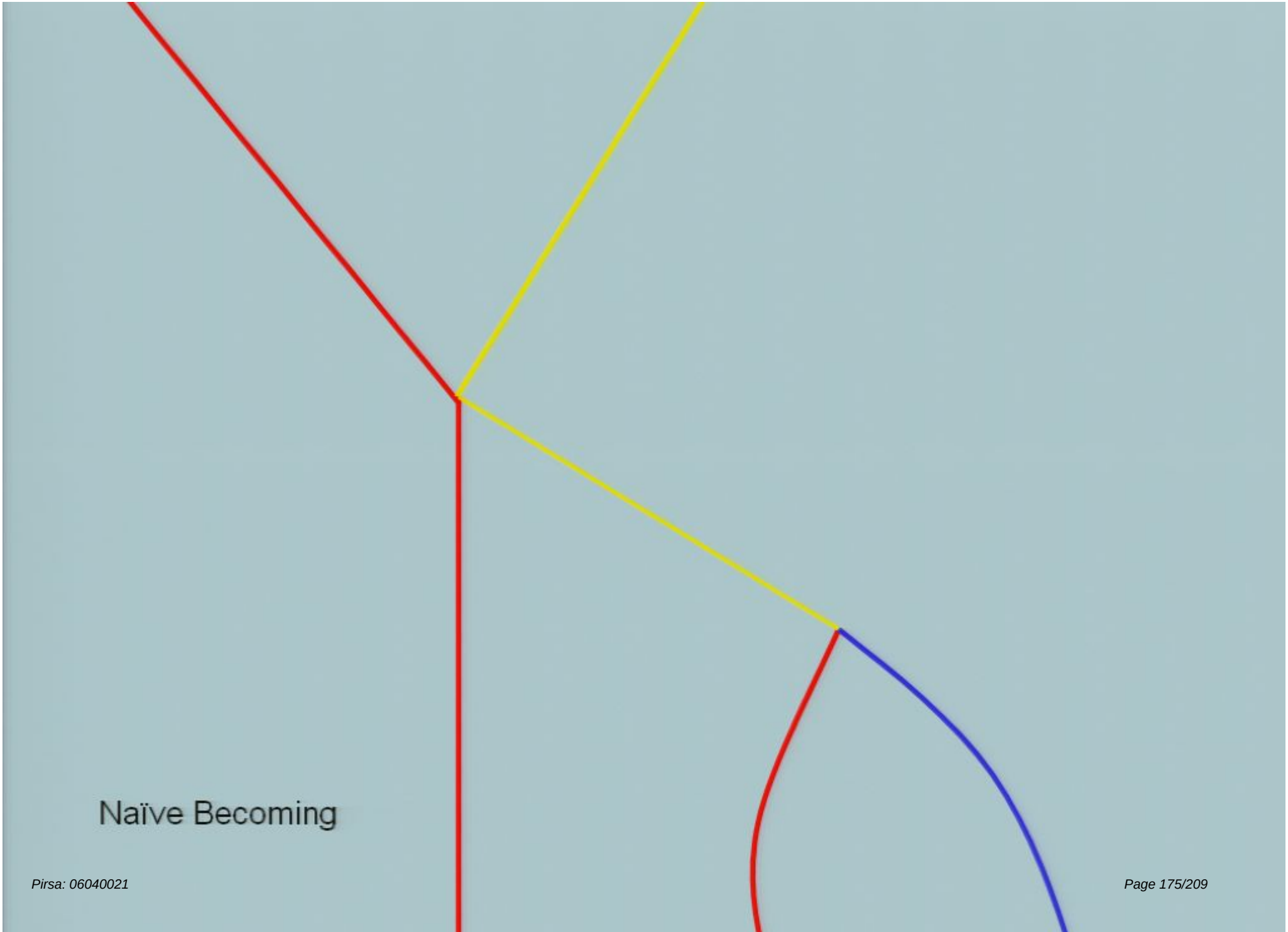
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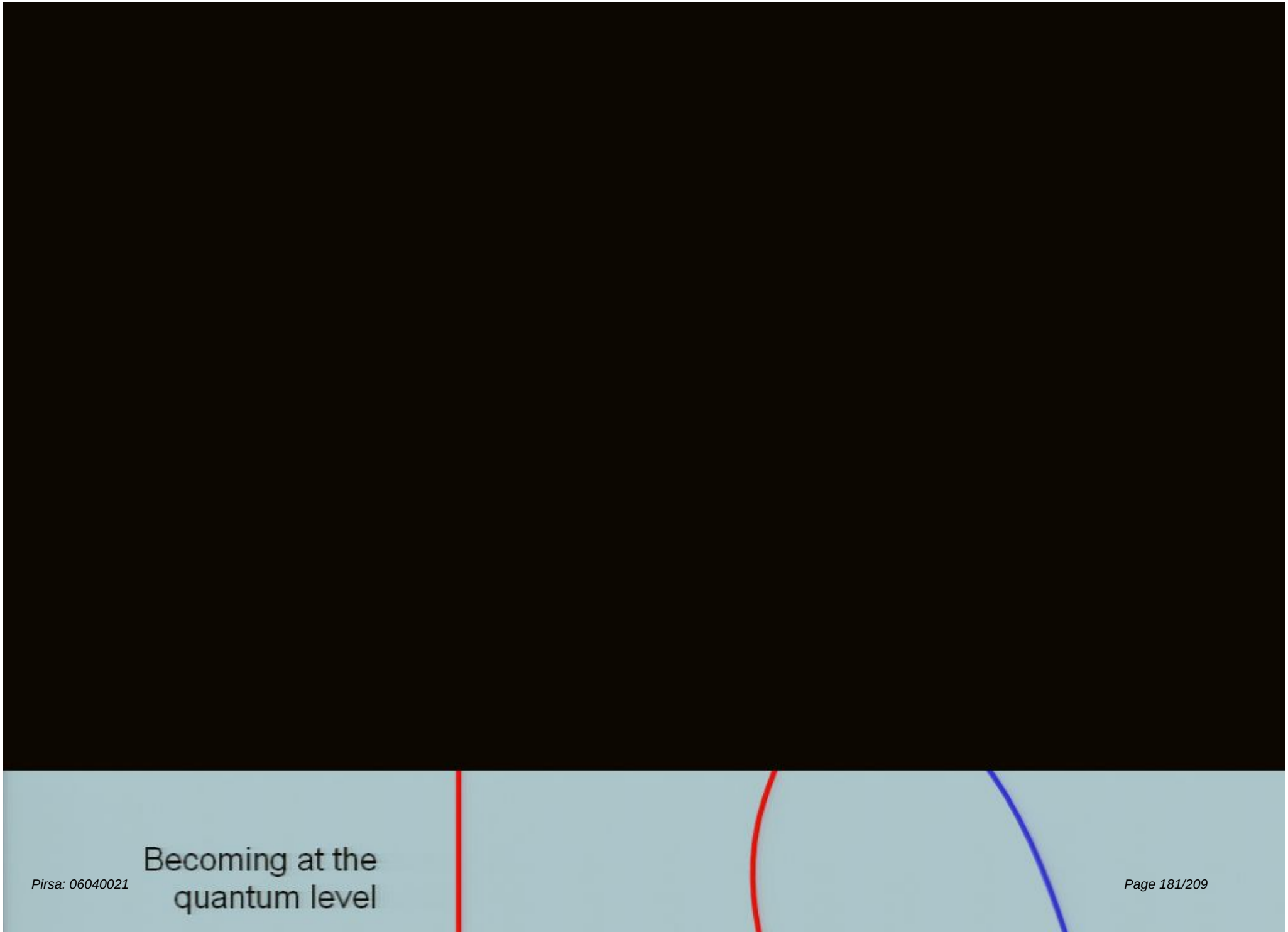
The spacetime zone associated with this interaction emerges only as its ***consequence.***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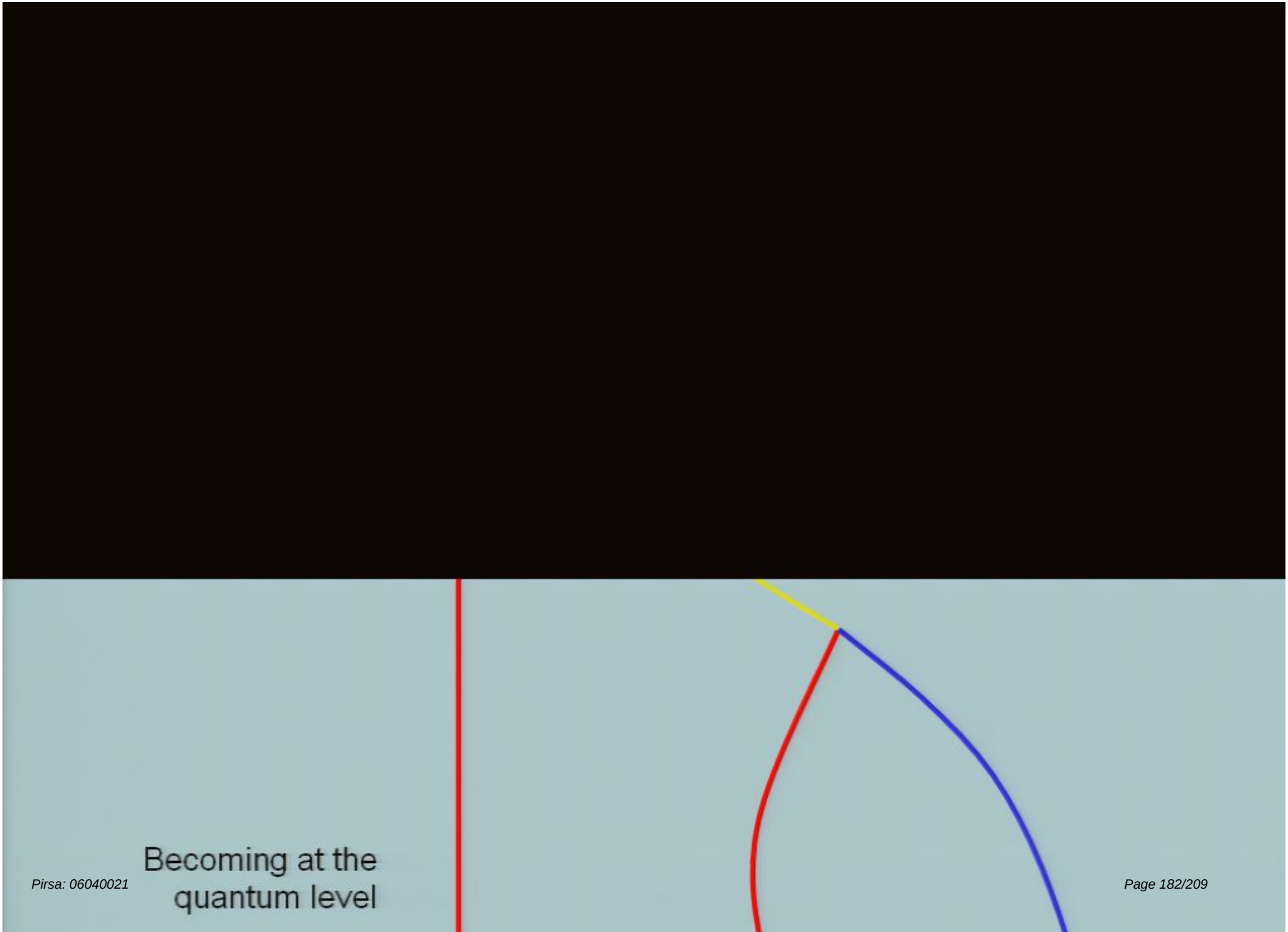
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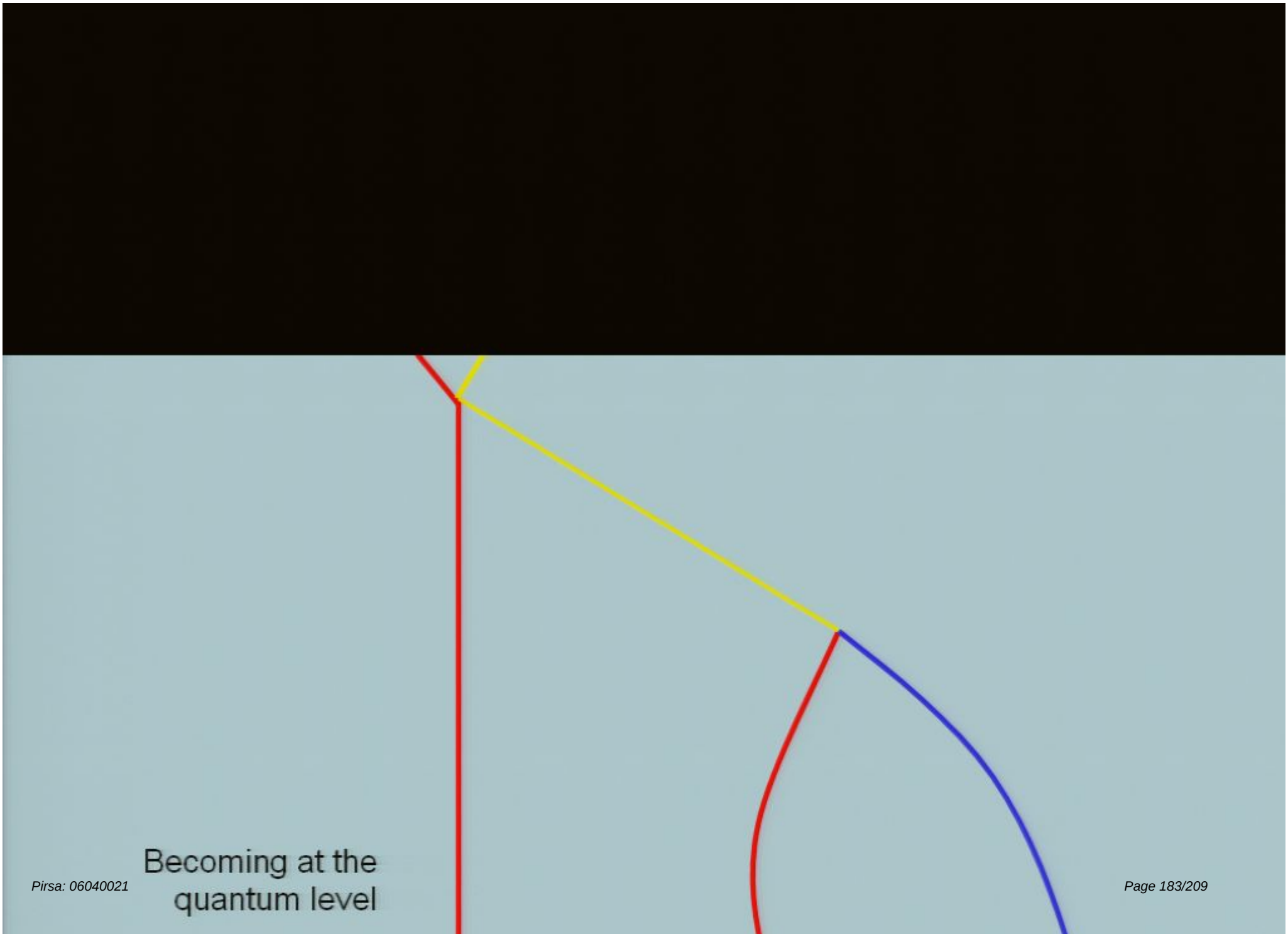
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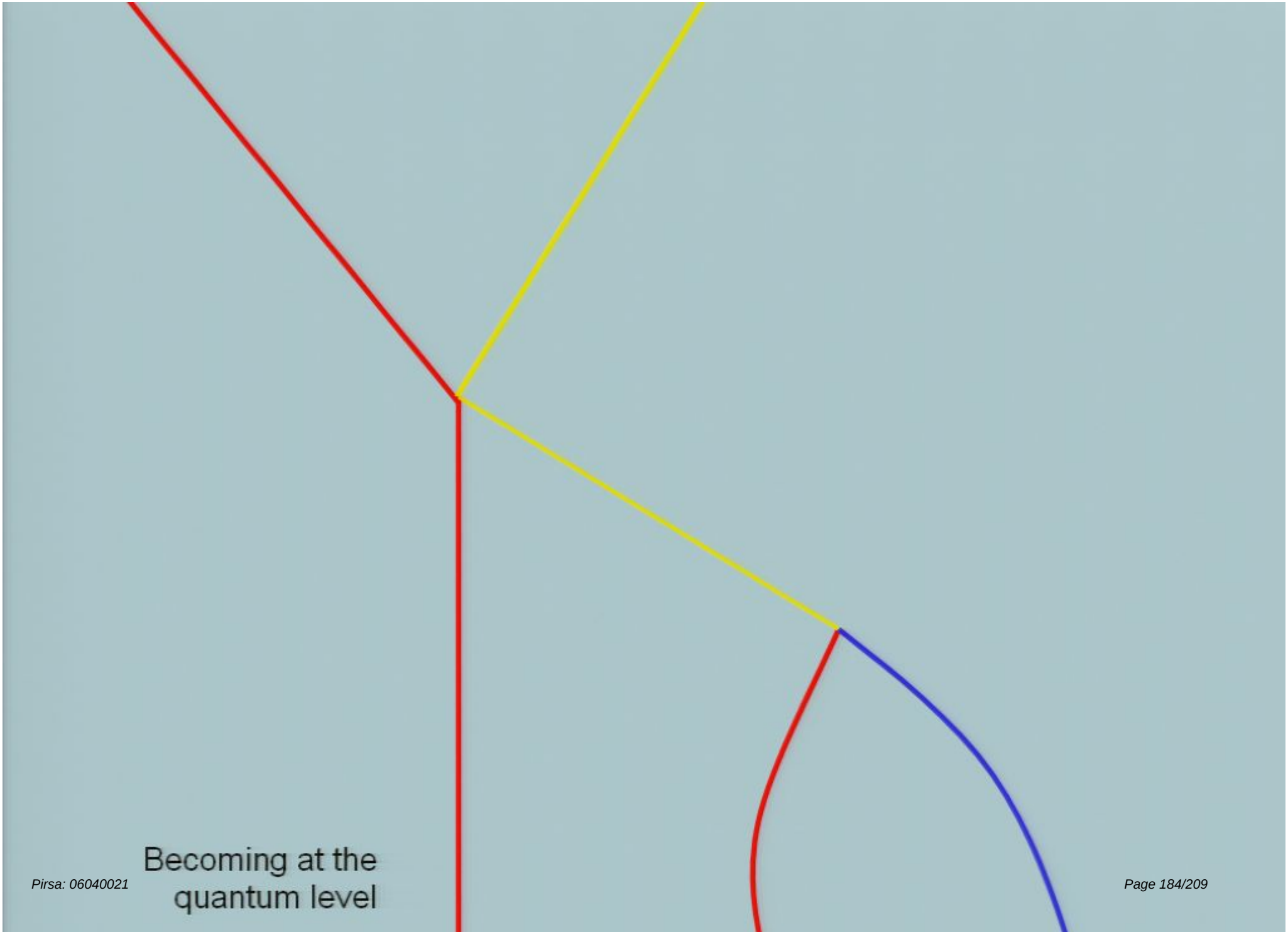
Becoming at the
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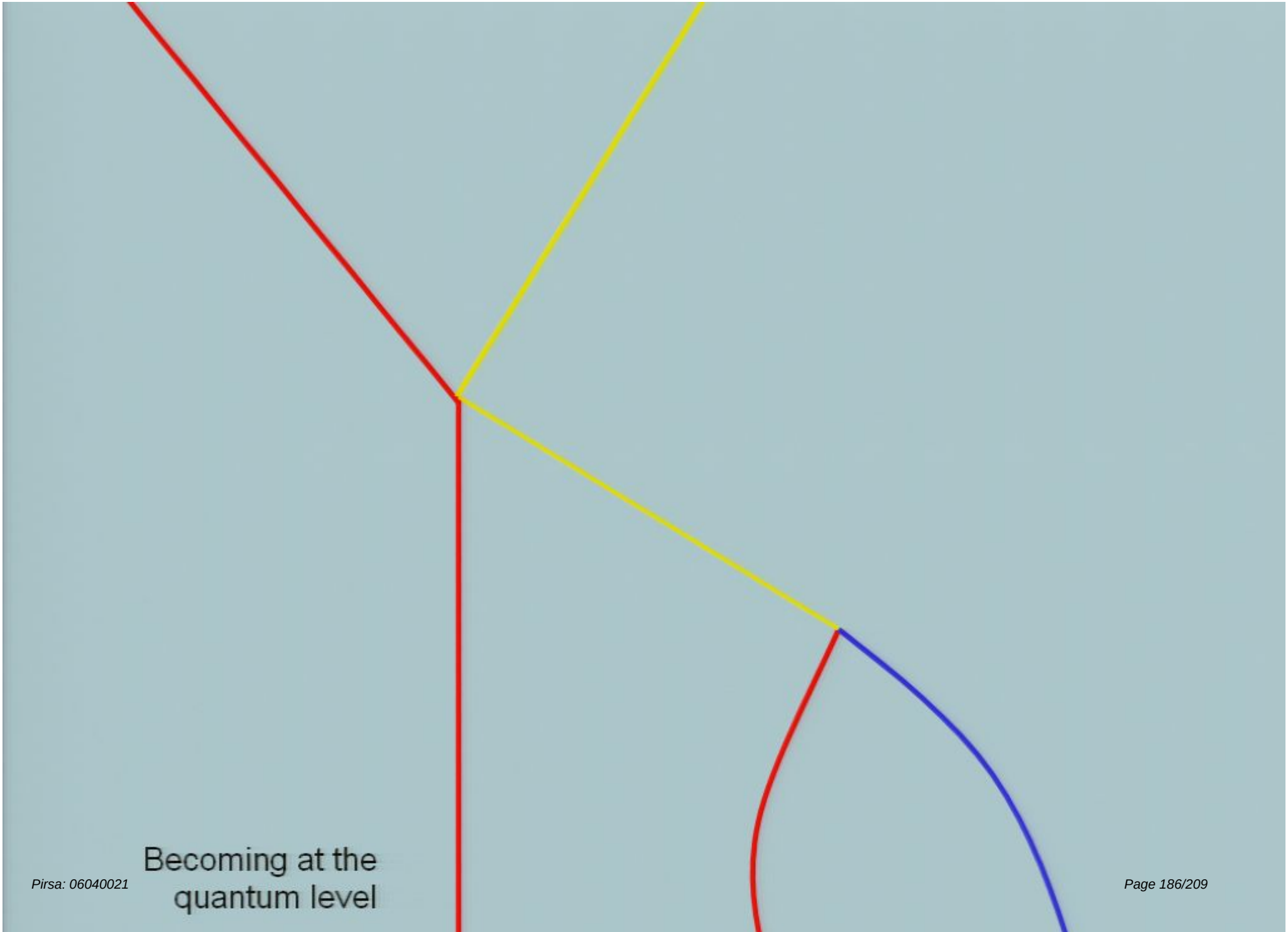
Special Relativity Dynamized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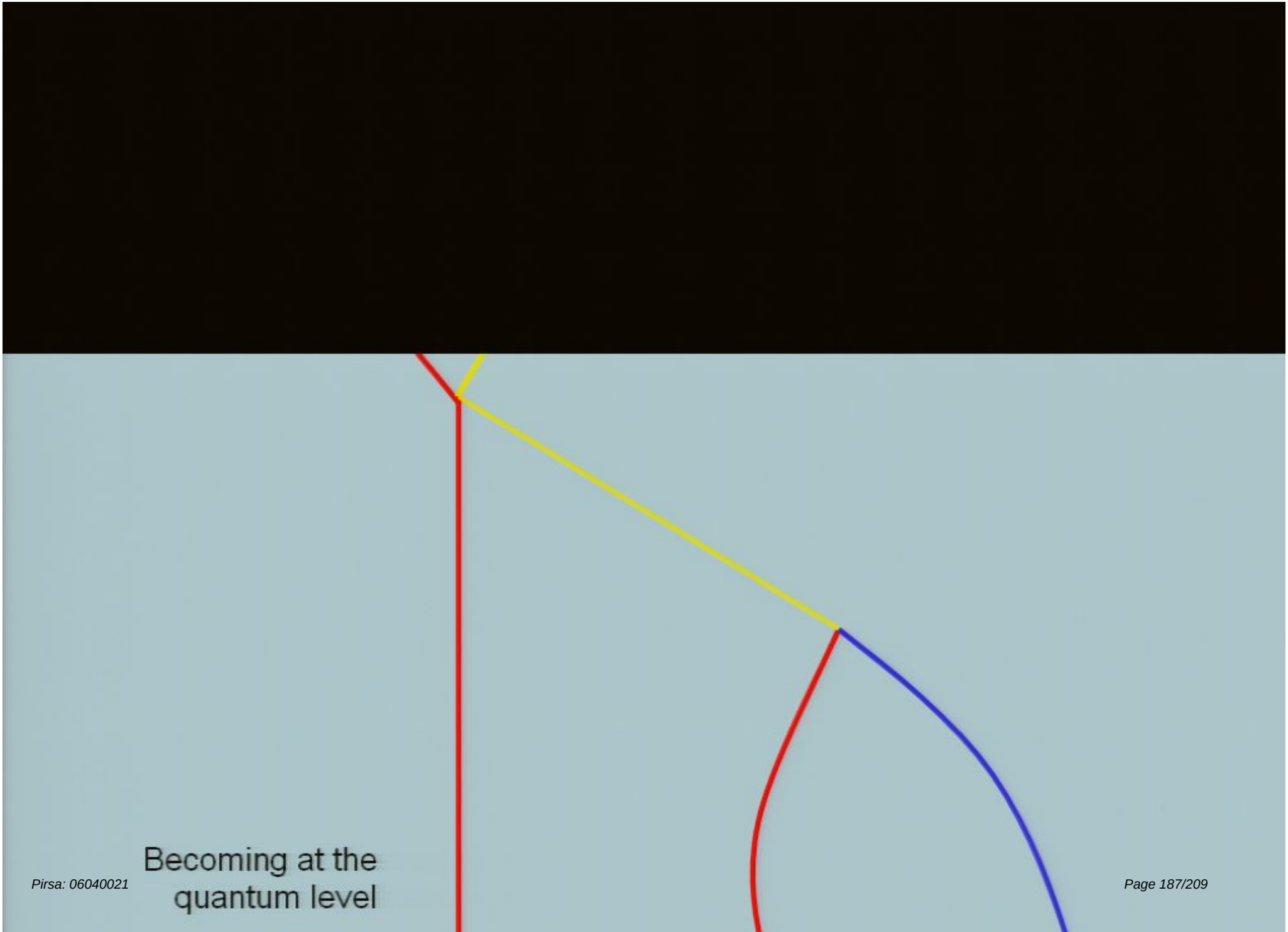
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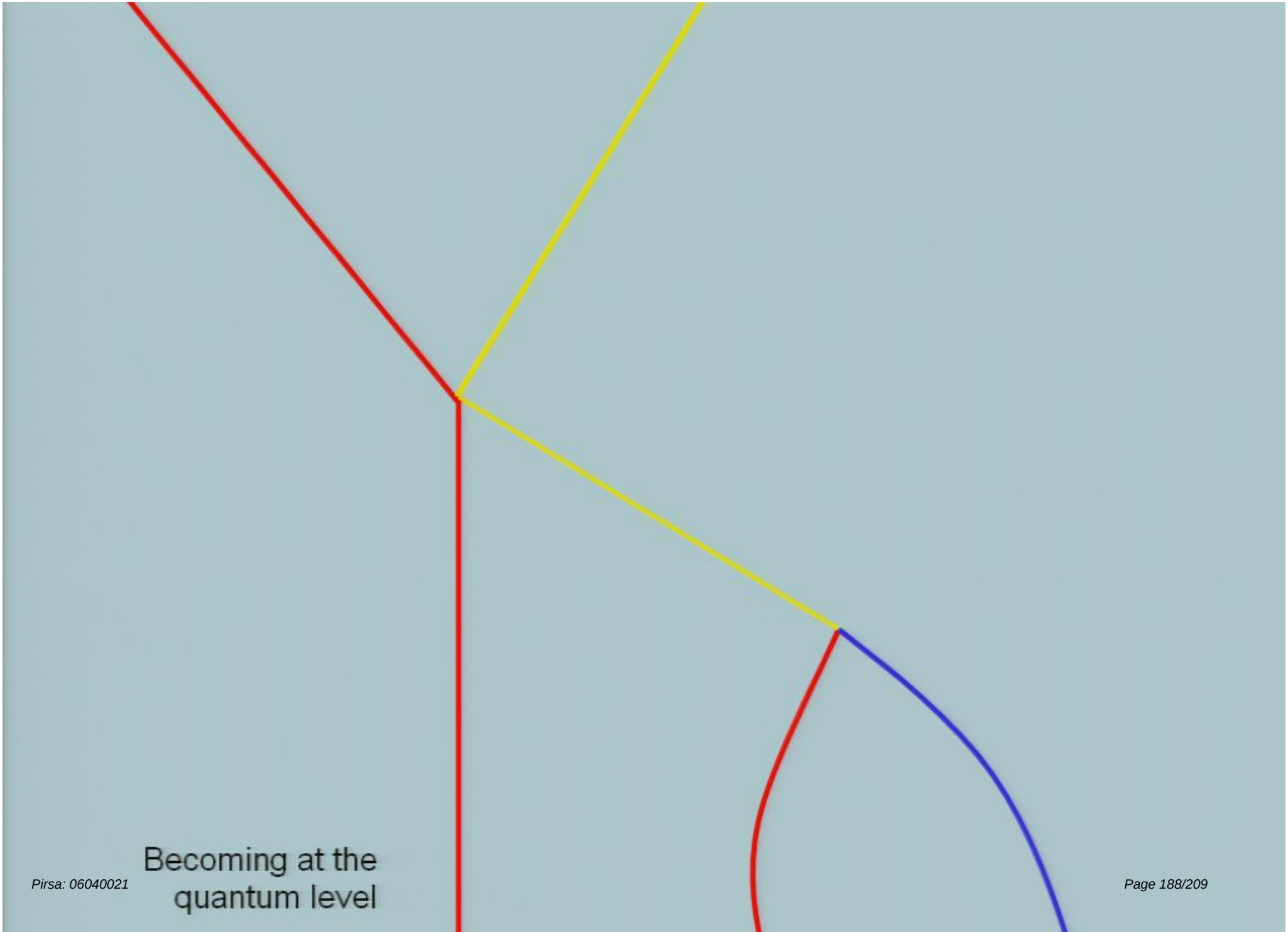
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Special Relativity Dynamized

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The speed of light is more basic than space and time

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

General Relativity Dynamized

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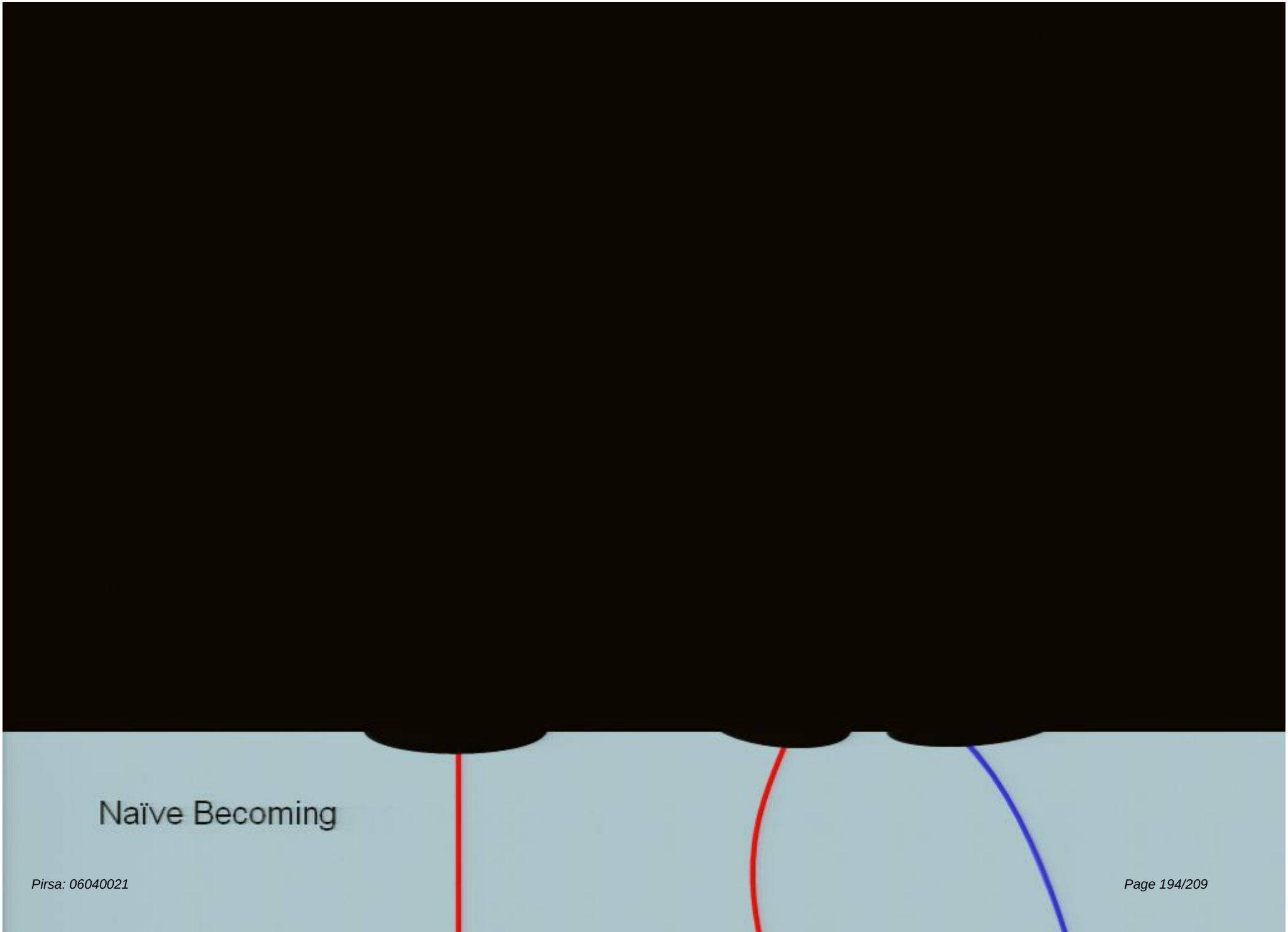
Mass gives rise not only to spacetime curvature but to “bumps” in the Now plane


Naïve Becoming

Consequence: The Origins of Time-Asymmetry

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Becoming is the master arrow of time

Consequence: The Origins of Time-Asymmetry

Becoming is the master arrow of time

Which creates spacetime intervals between events

Consequence: Mach Dynamized

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

Thereby, *Force* is Dynamized

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The wave function, upon "measurement," gives rise not only to the particles' position and momentum but to the entire spacetime region within which it ***could*** have resided.

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Take all pre-big-bang scenarions and apply them to the pre-spacetime stage of every event

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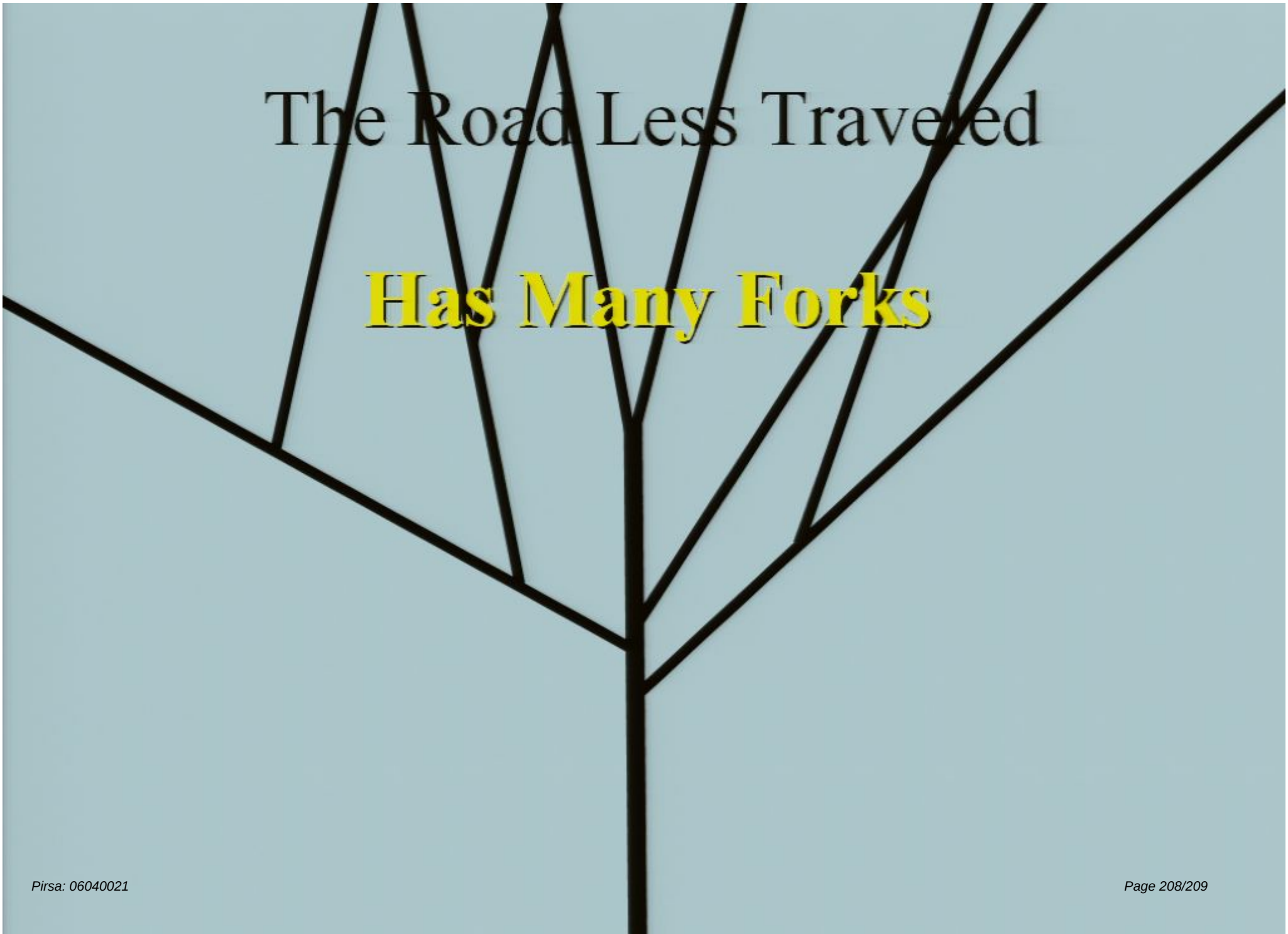
E.g., Compactification as the mechanism for quantum collapse

The Road Less Traveled


The Road Less Traveled
Has Many Forks

What a pity to die at the dawn of relativity!

(Herman Minkowski, 1909)