Title: A Computational Grand-Unified Theory

Date: Feb 03, 2010 04:00 PM

URL: http://pirsa.org/10020037

Abstract: Are Quantum Mechanics and Special Relativity unrelated theories? Is Quantum Field Theory an additional theoretical layer over them? Where the quantization rules and the Plank constant come from? All these questions can find answer in the computational paradigm: "the universe is a huge quantum computer".

In my talk I'll take the computational-universe paradigm as genuine theoretical framework, and analyze some relevant implications. A new kind of quantum field theory emerges: "Quantum-Computational Field Theory" (QCFT). I will show how in QCFT Special Relativity unfolds from the fabric of the computational network, which also naturally embeds gauge-invariance, and even the quantization rule and the Planck constant, which thus resort to being properties of the underlying causal tapestry of space-time. In this way Quantum Mechanics remains the only theory needed to describe the computational-universe. I will analyze few simple toy-models in order to explore the mathematical structure of QCFT.

The new QCFT has many advantages versus the customary field theoretical framework, solving a number of logical and mathematical problems that plague quantum field theory. One further advantage of QCFT is the possibility of changing the computational engine without changing the field-theoretical framework. One can thus consider different kind of engines, e.g. classical, quantum, super-quantum, and even input-output networks with no pre-established causal relations, which are very interesting for addressing the problem of Quantum Gravity.

QCFT opens a large research line: I argue that this program should be addressed soon in the particle physics domain, before entering Quantum Gravity, notwithstanding the experimental success of the usual quantum field theory. It will also be the first test of the Lucien Hardy's program on Quantum Gravity.

Reference: arXiv:1001.1088 (http://arxiv.org/abs/1001.1088)

QUIt quantum information theory group

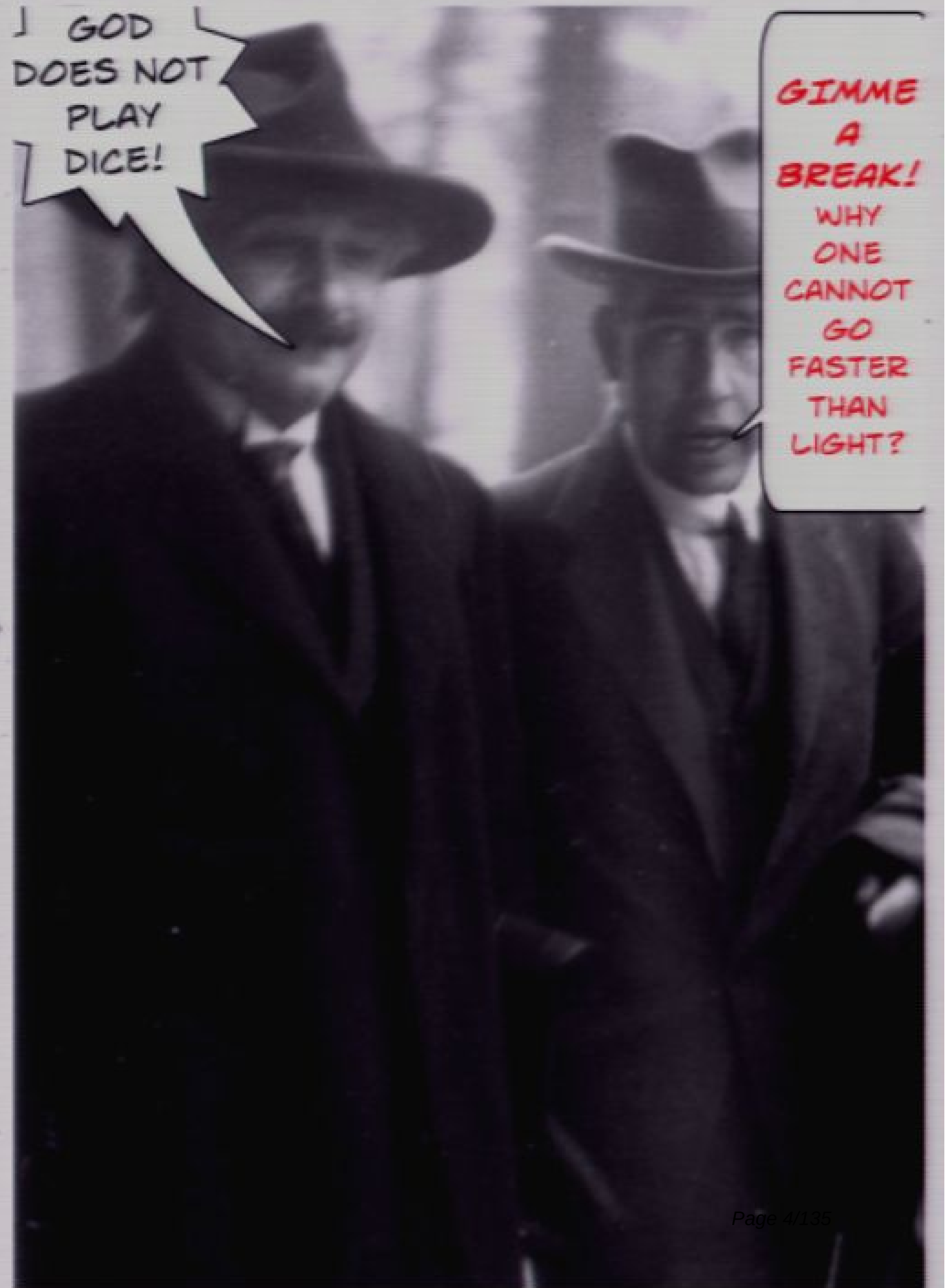
A COMPUTATIONAL GUT

Giacomo Mauro D'Ariano

Dipartimento di Fisica "A.Volta", Università di Pavia

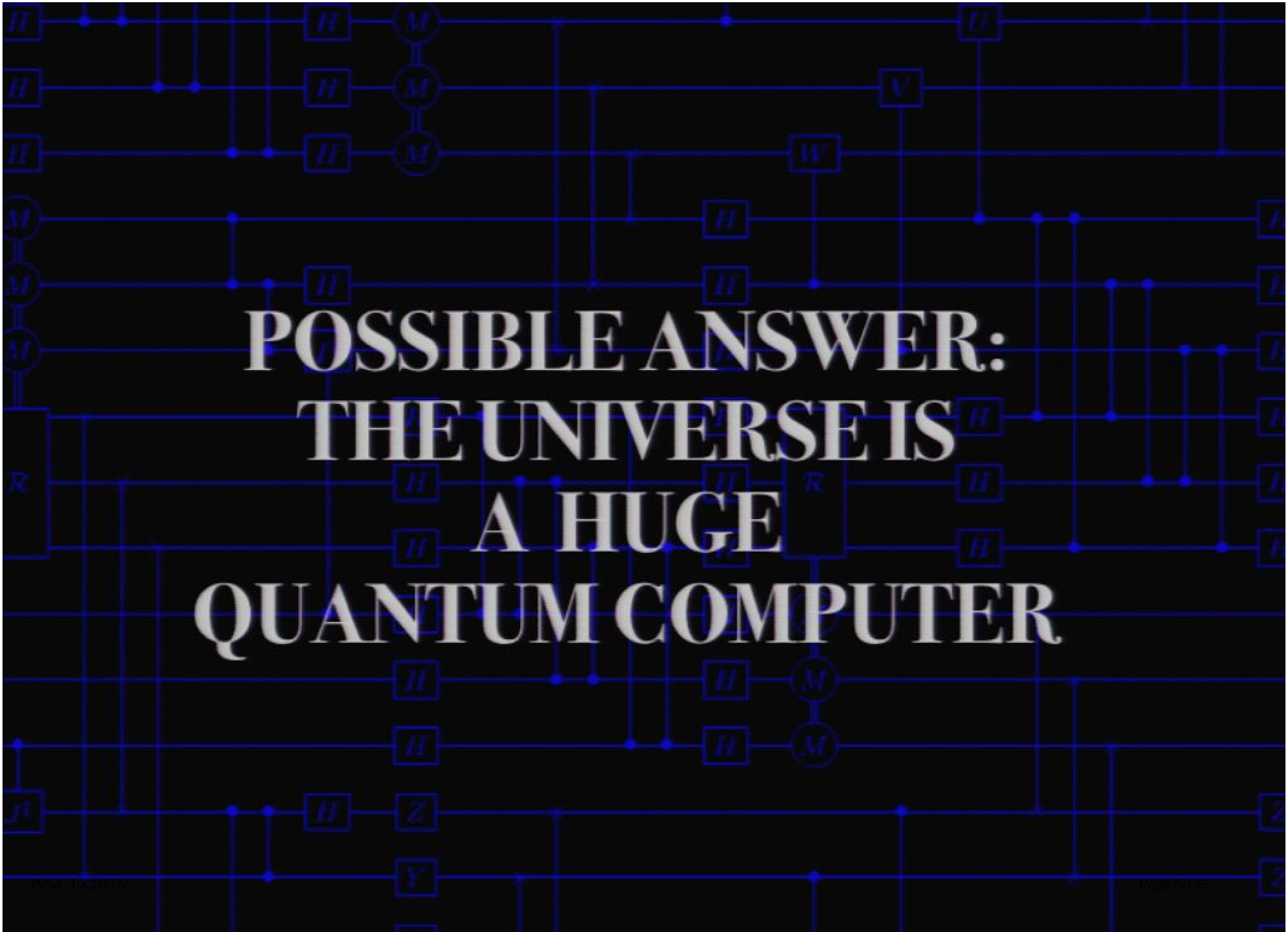
WHY QUANTUM?

WHY QUANTUM? WHY RELATIVITY?



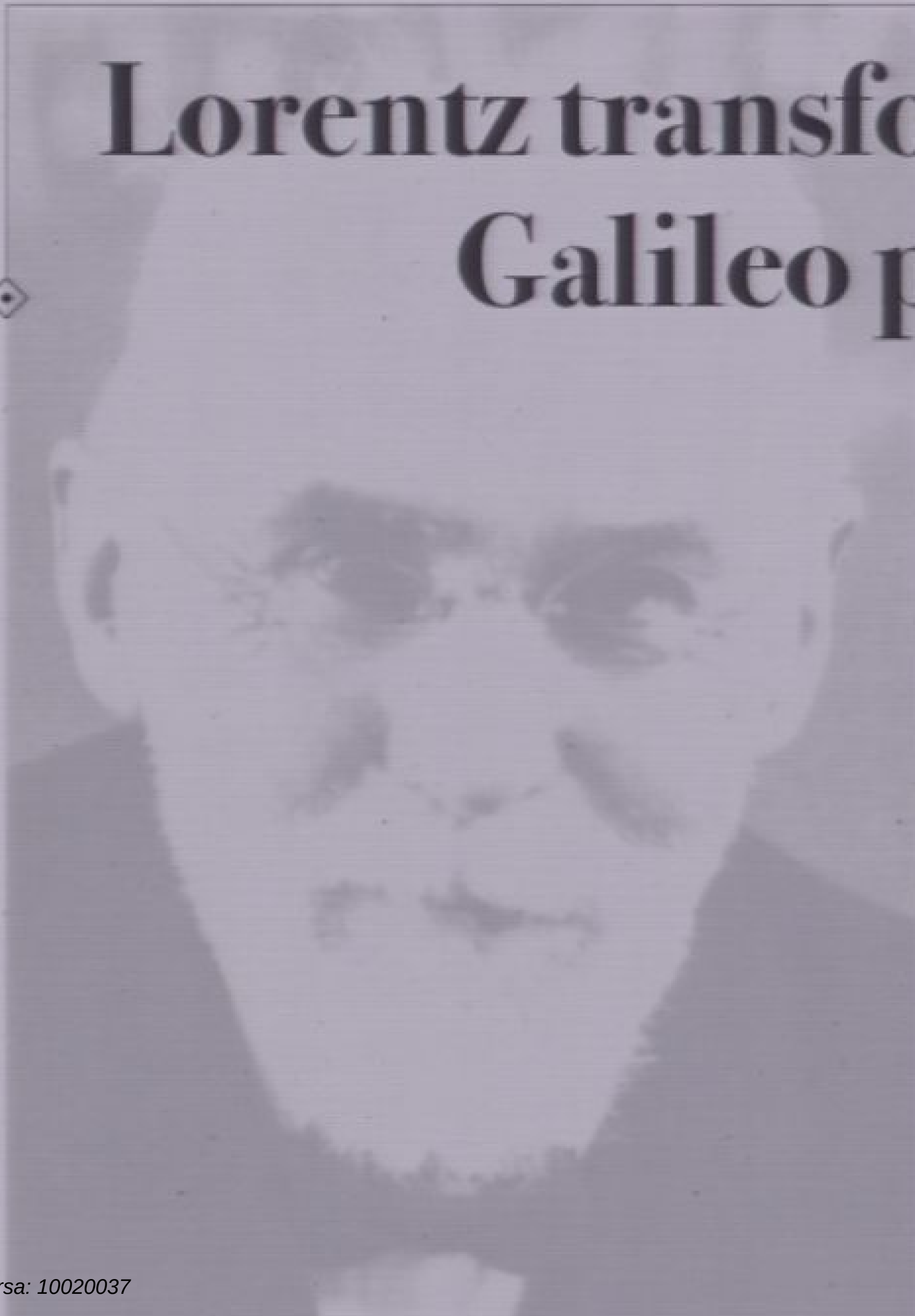
WHY QUANTUM? WHY RELATIVITY?

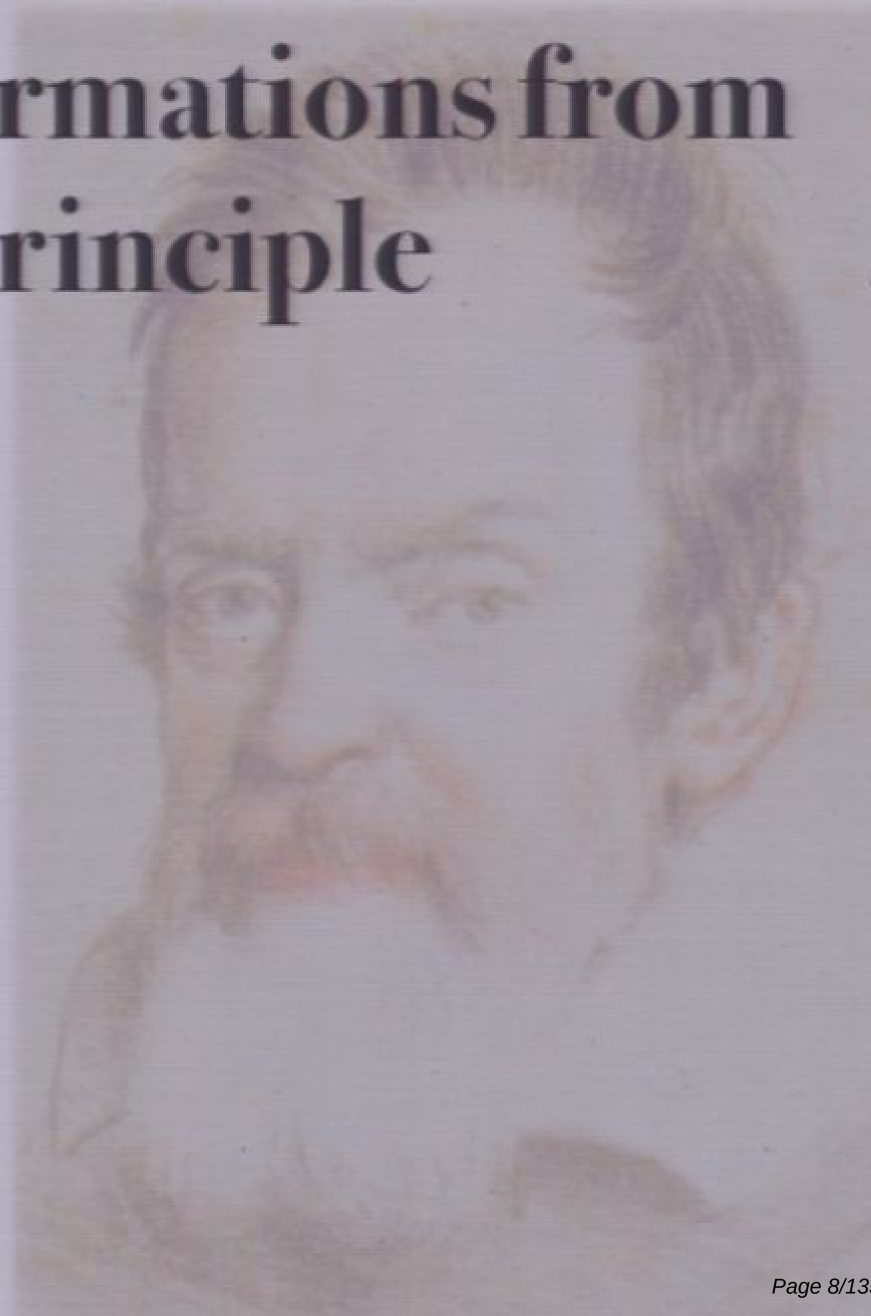
- * Are Quantum Theory and Special Relativity unrelated theories?
- * Is Quantum Field Theory (QFT) an additional theoretical layer over QT and SR?
- * Where the quantization rules and the Planck constant come from?


POSSIBLE ANSWER:
THE UNIVERSE IS
A HUGE
QUANTUM COMPUTER

HOW RELATIVITY EMERGES FROM THE COMPUTATION?

Lorentz transformations from Galileo principle





Lorentz transformations from Galileo principle

* Galileo principle includes homogeneity and isotropy of space and homogeneity of time.

* On the assumption of isotropy and homogeneity of space and homogeneity of time along with symmetry between the two references, the most general transformations of reference system are the Lorentz transformations with a parameter Ω with the dimensions of a velocity, which is independent on the relative velocity of frames.

Special Relativity from computational network

Lorentz transformations from Galileo principle

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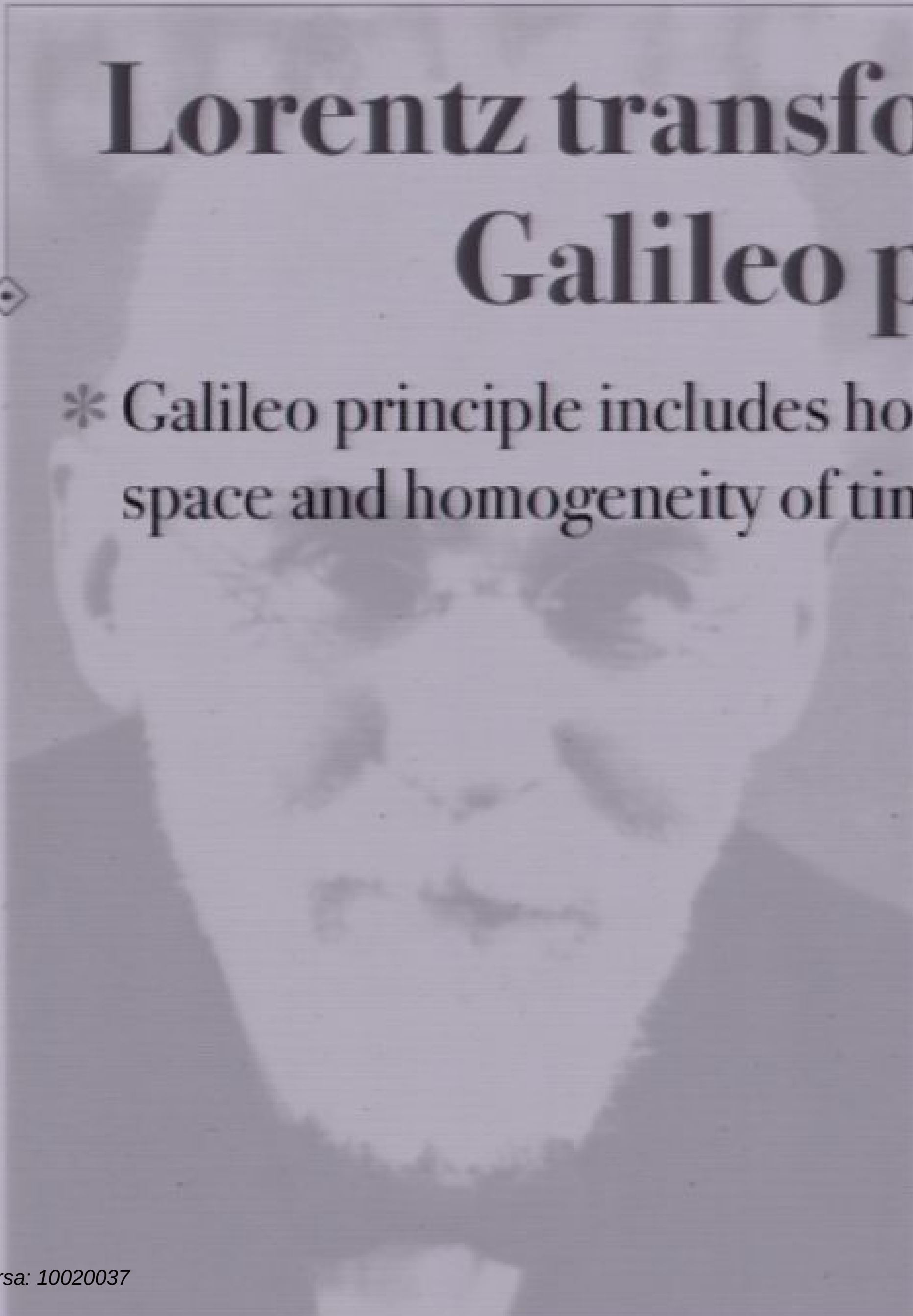

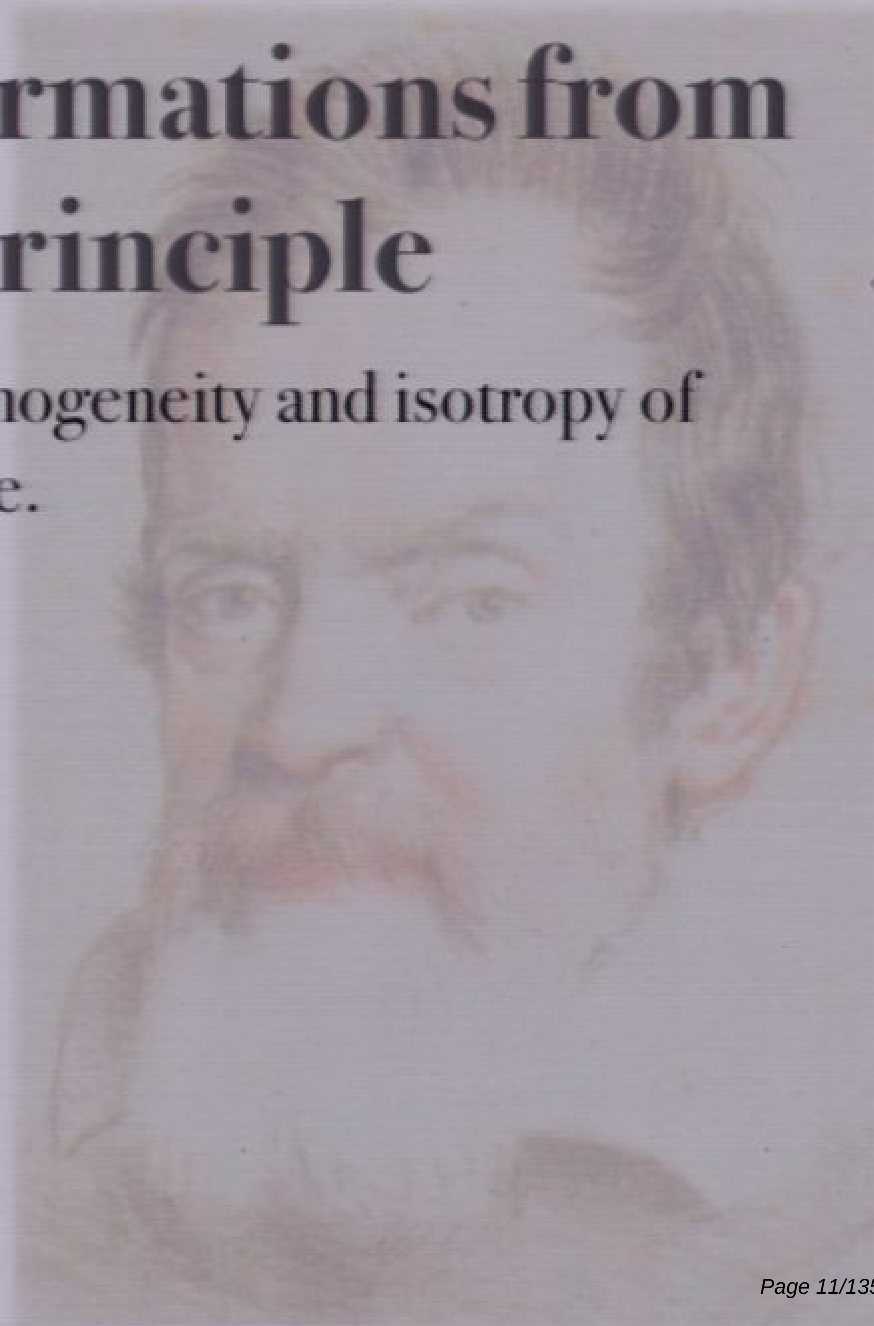

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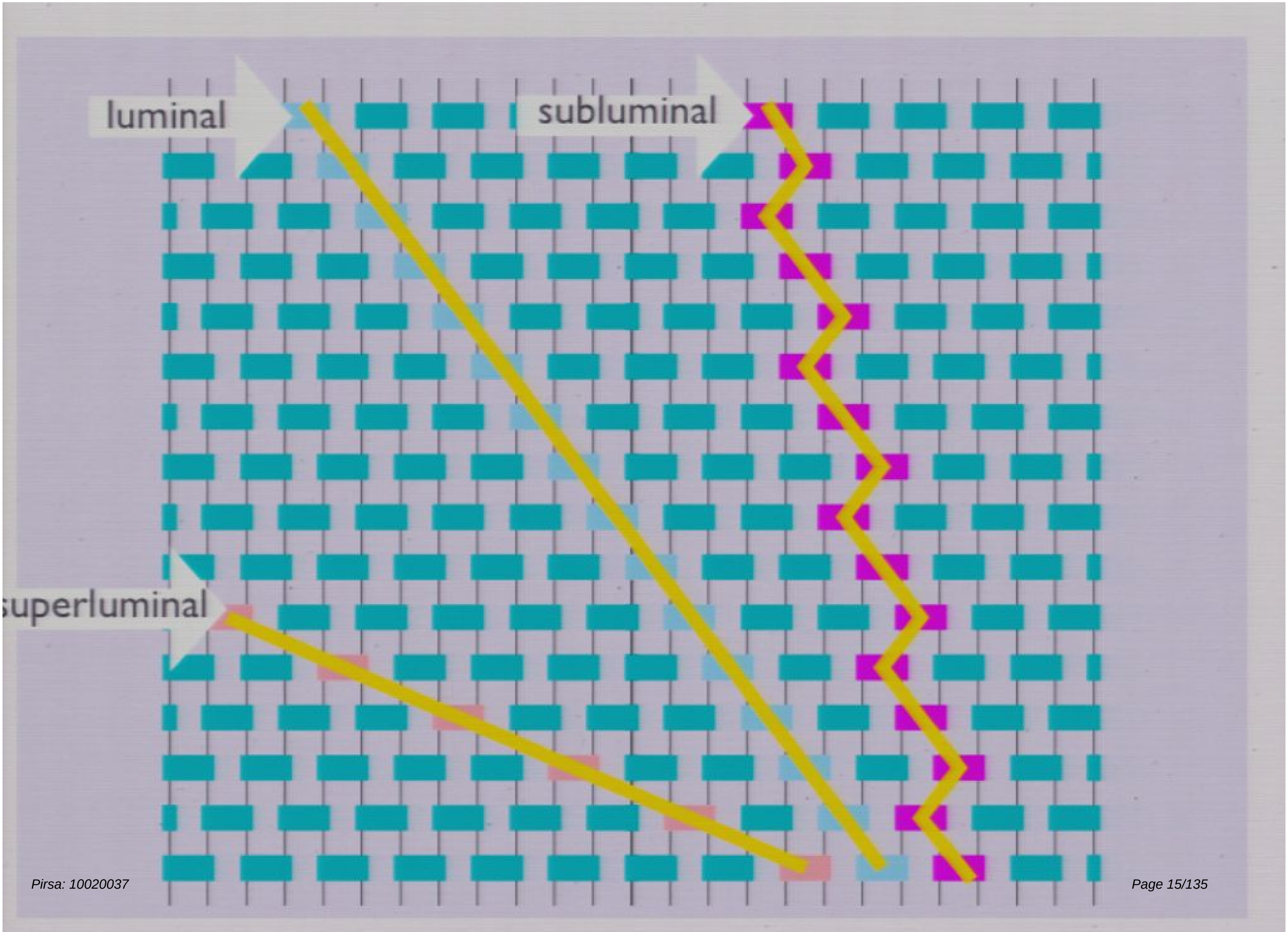
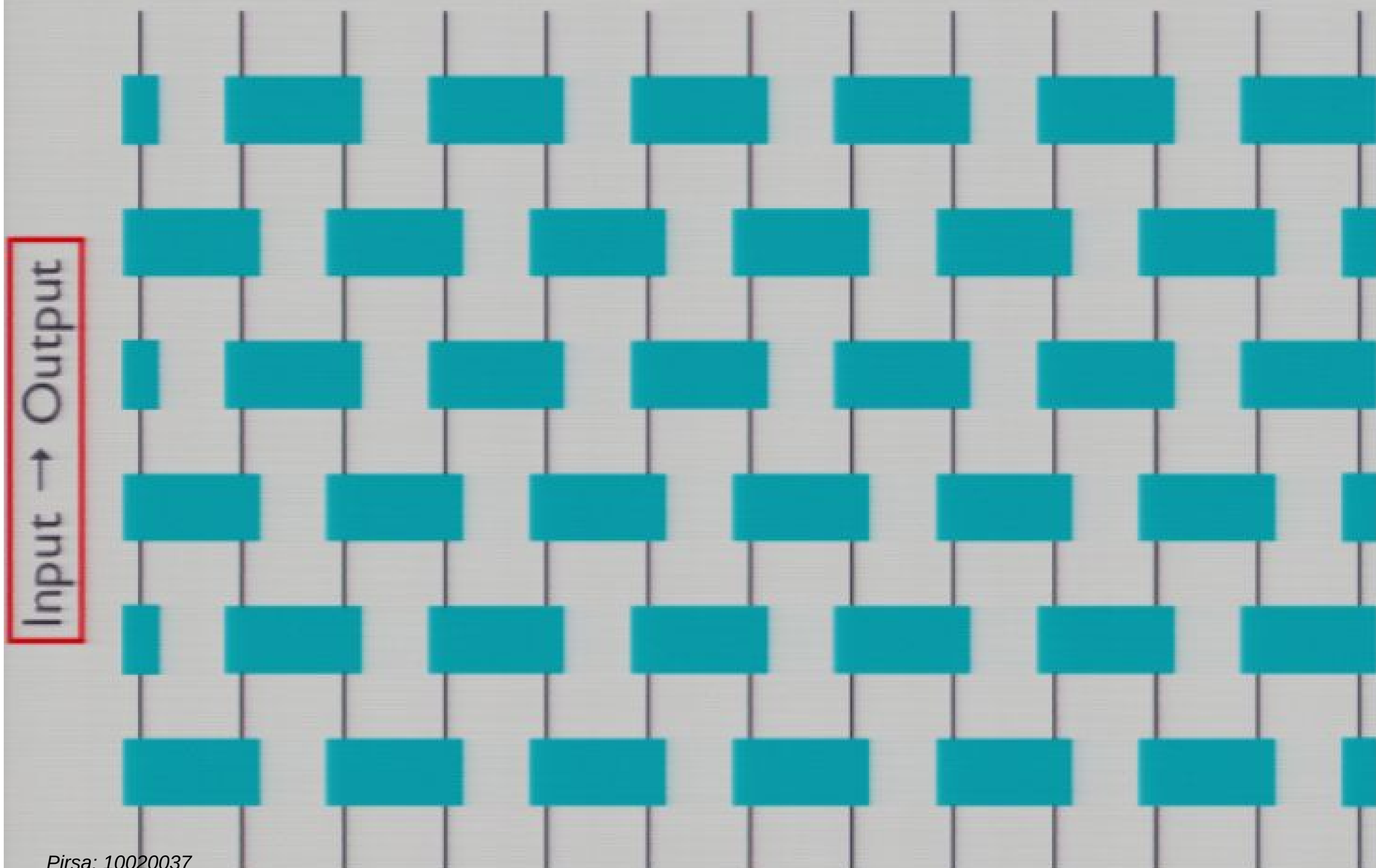
Special Relativity from computational network

Special Relativity from computational network

- Take a computational circuit which is uniform and isotropic.
- Take the "continuum limit" → space-time.


luminal
subluminal
superluminal

Relativity from QT
(more generally from causality)



Relativity from QT

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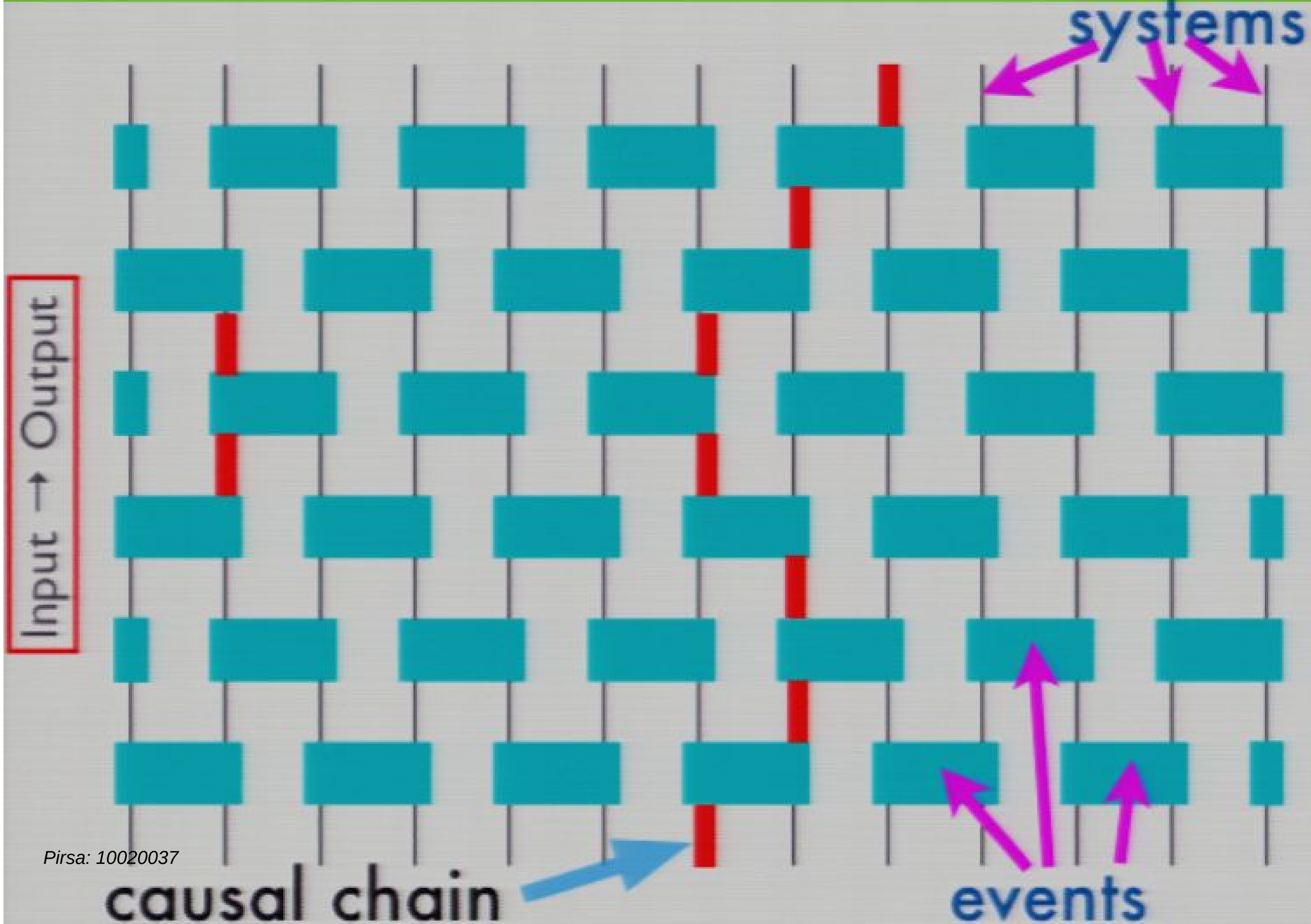
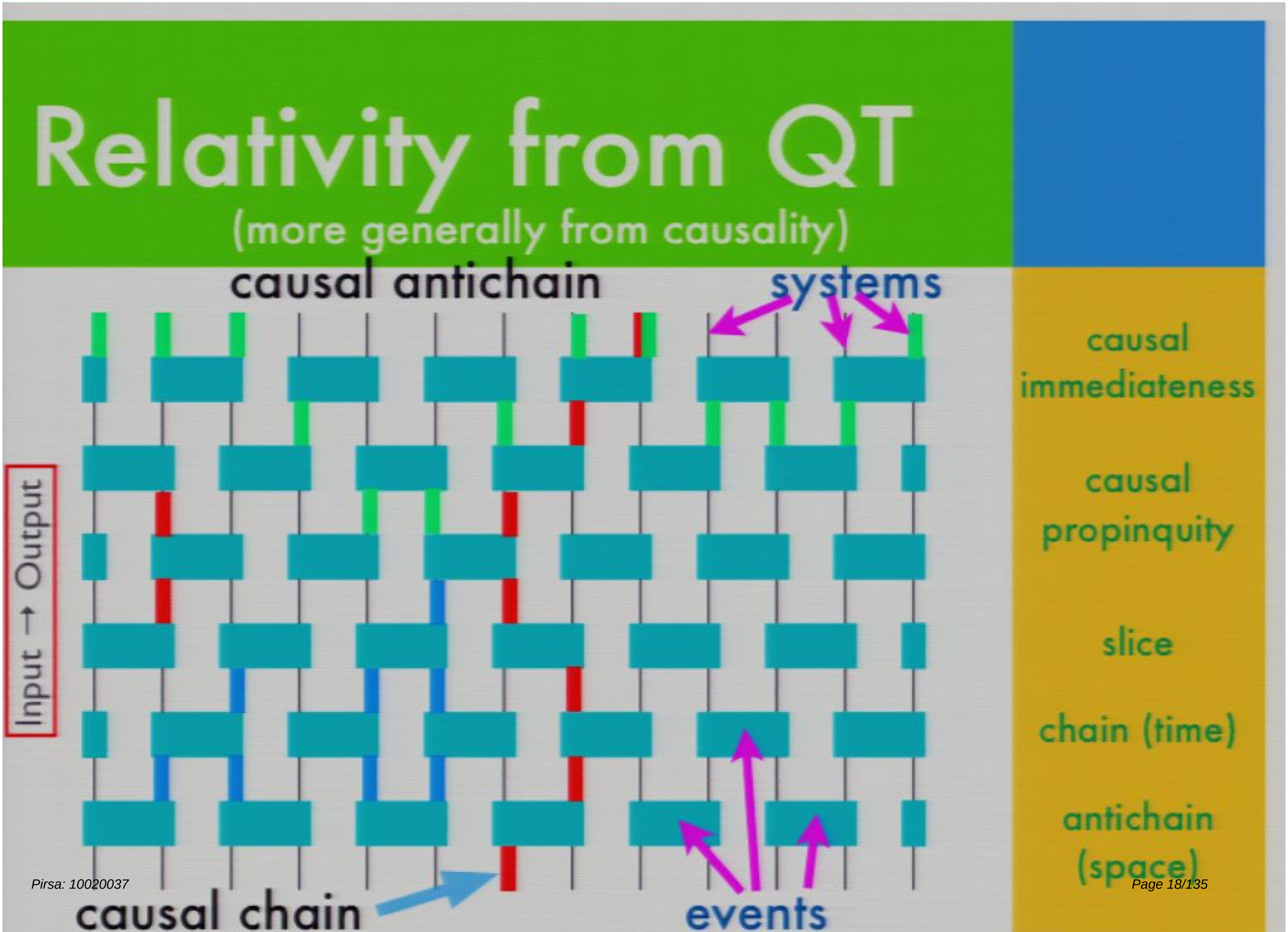
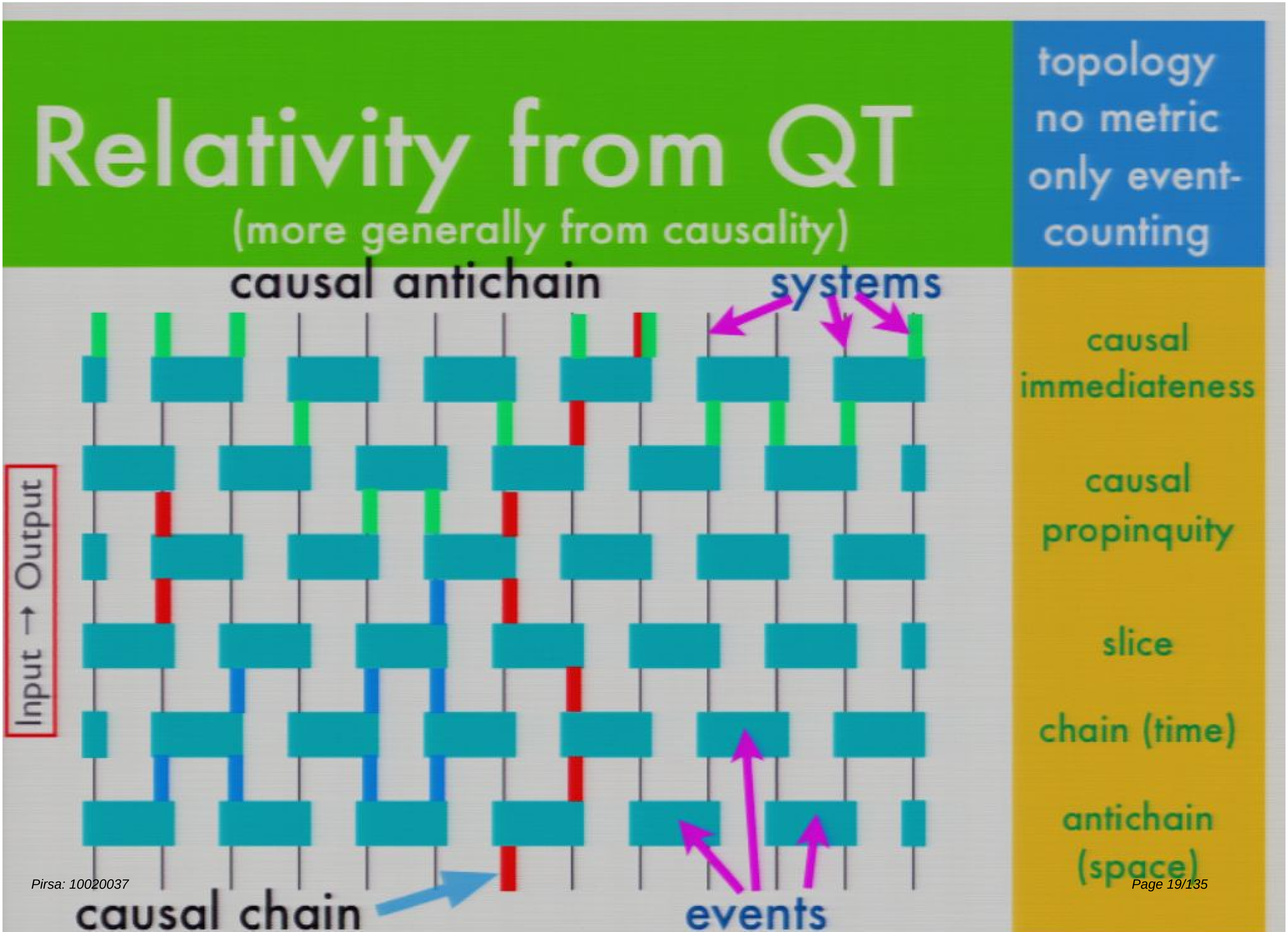


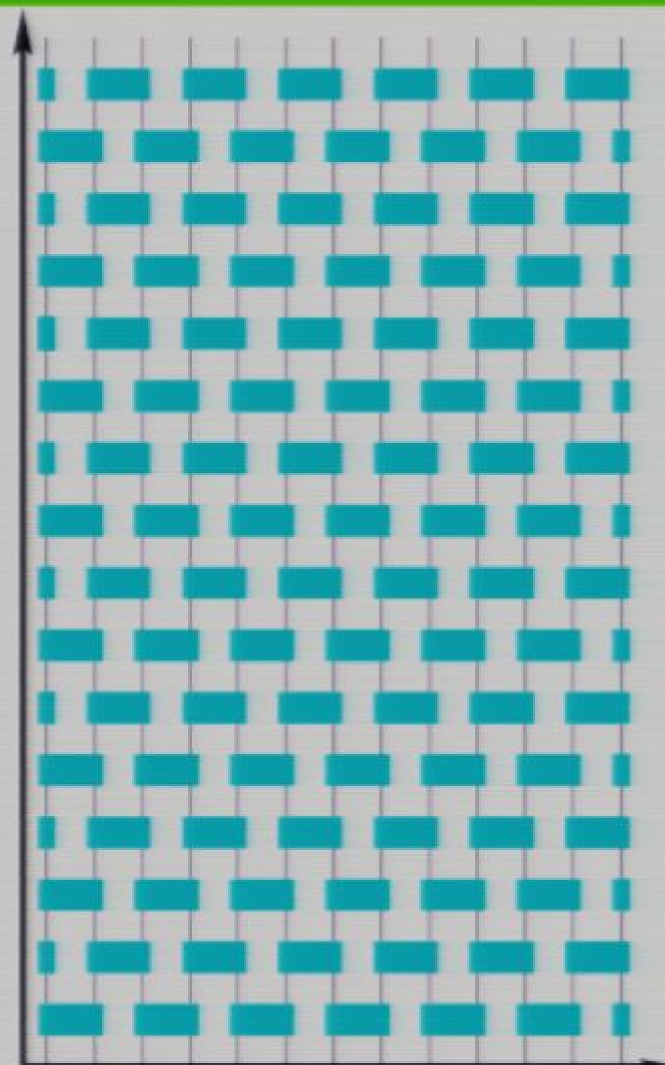
causal immediateness

chain (time)

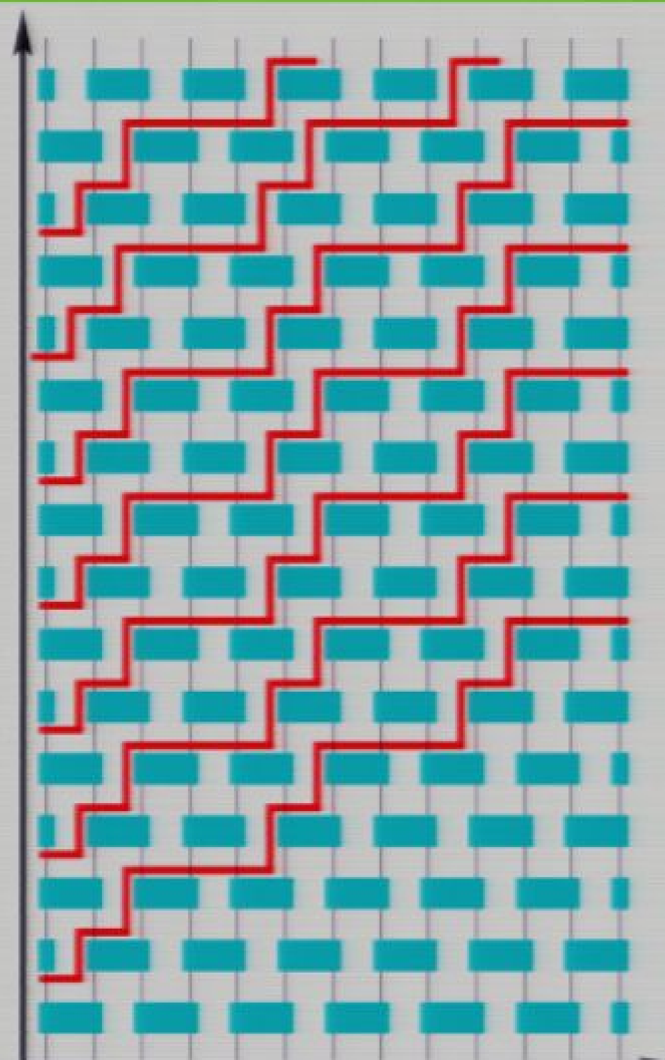

Relativity from QT
(more generally from causality)
causal antichain
systems
causal immediateness
causal propinquity
slice
chain (time)
antichain (space)
Input → Output
causal chain
events


Relativity from QT
(more generally from causality)
topology
no metric
only event-
counting
causal antichain
systems
Input → Output
causal immediateness
causal propinquity
slice
chain (time)
antichain (space)
causal chain
events

Relativity from QT

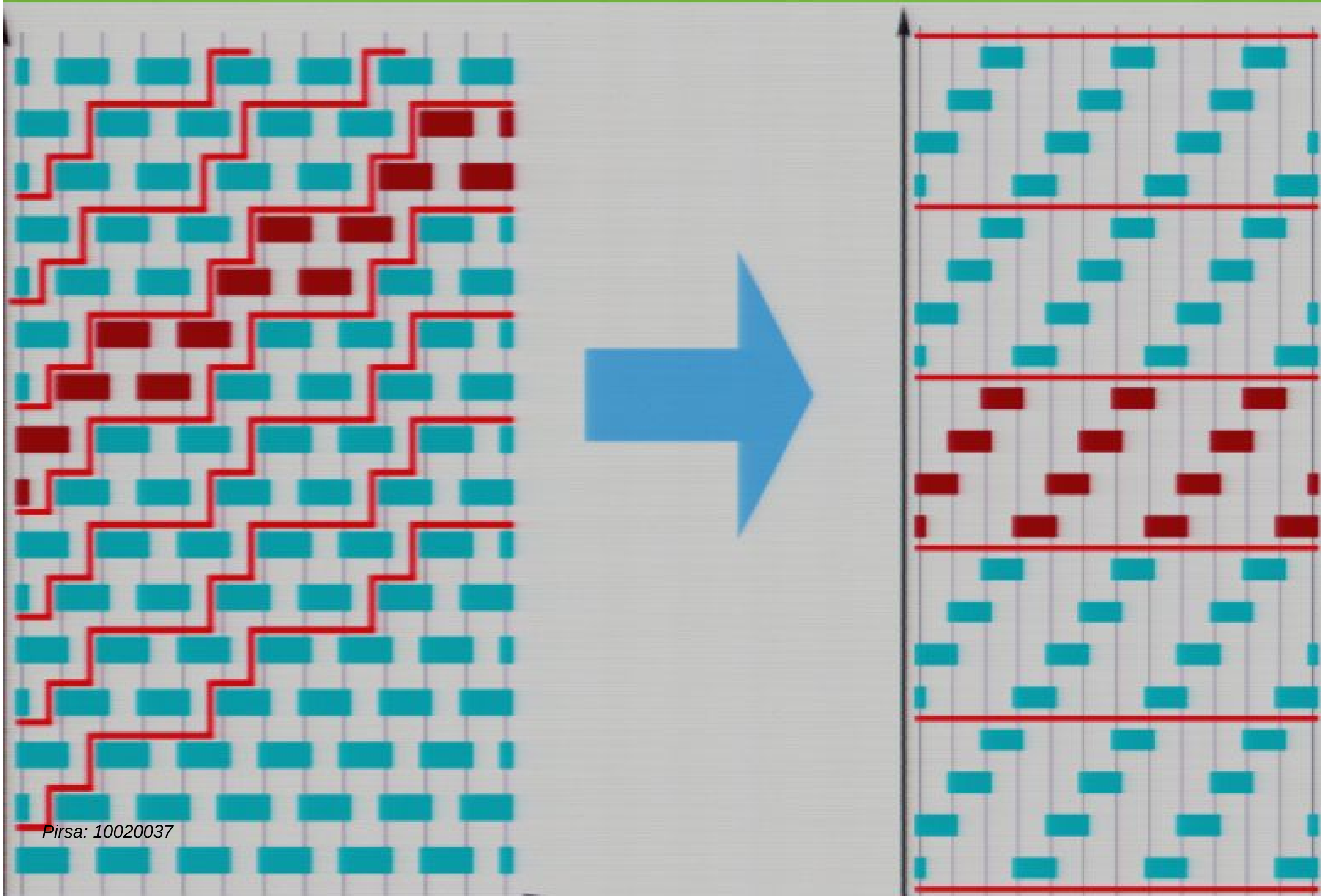


Relativity from QT



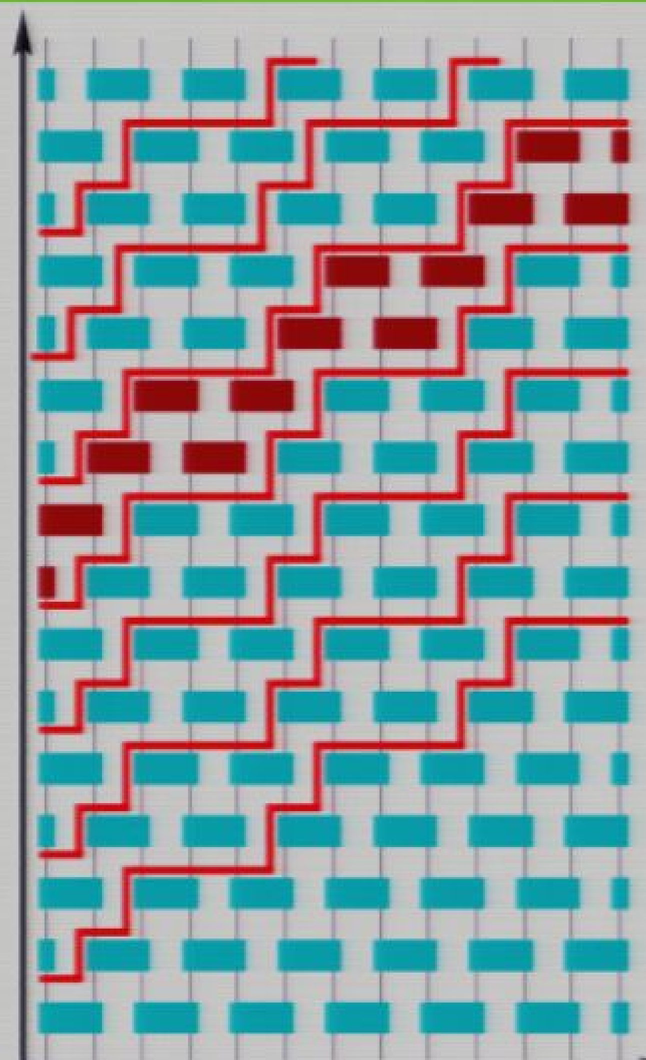
build a uniform foliation

Relativity from QT

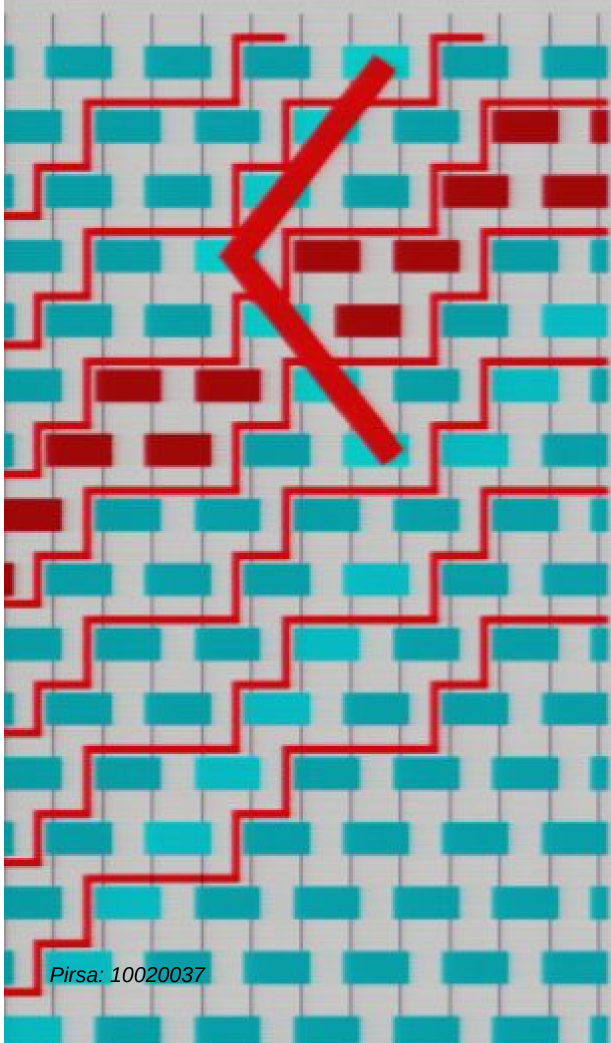


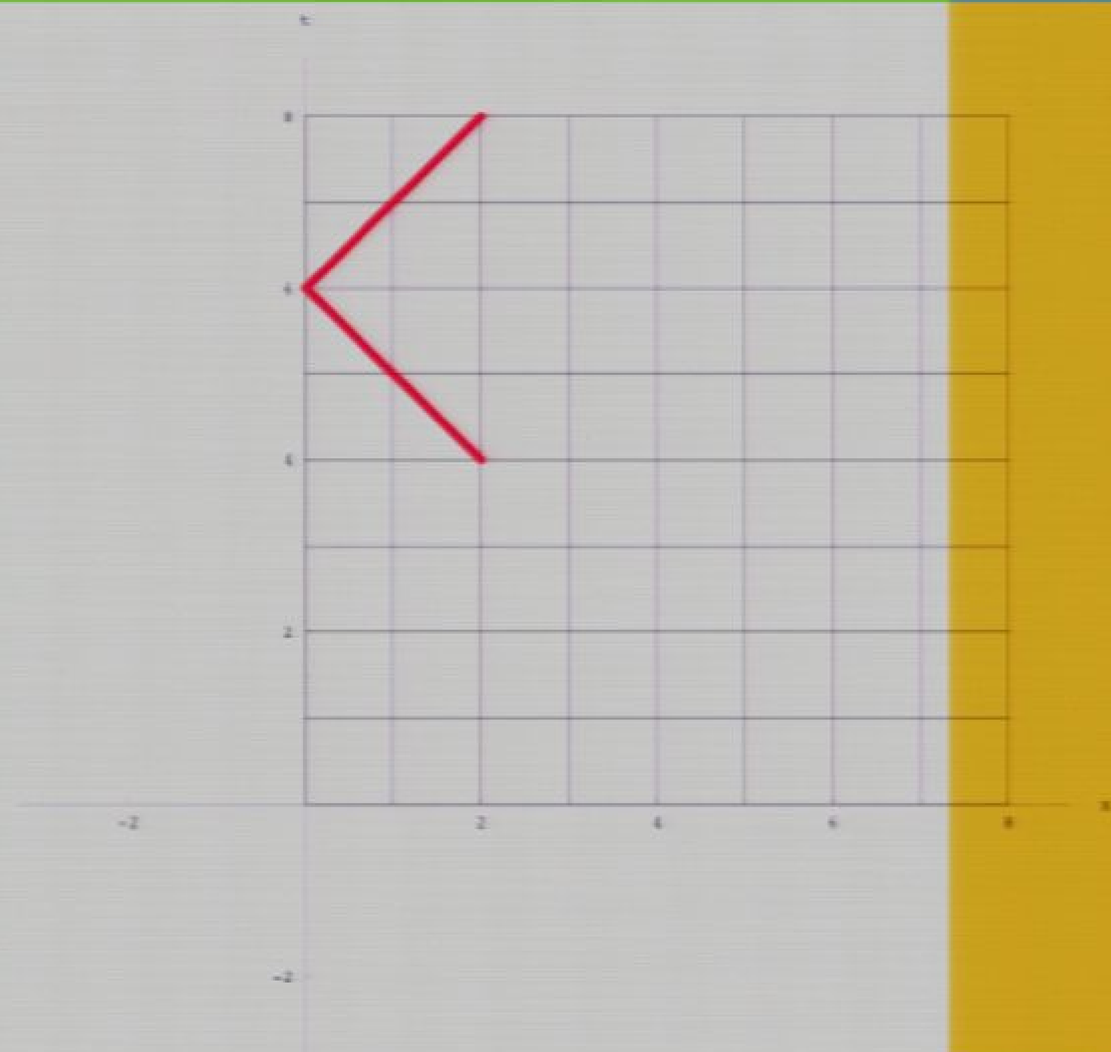
change reference

Relativity from QT

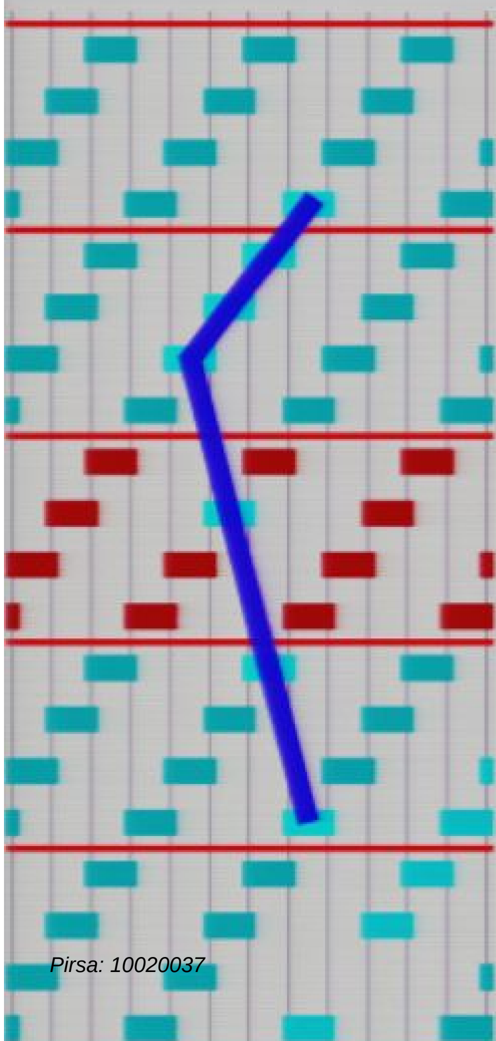


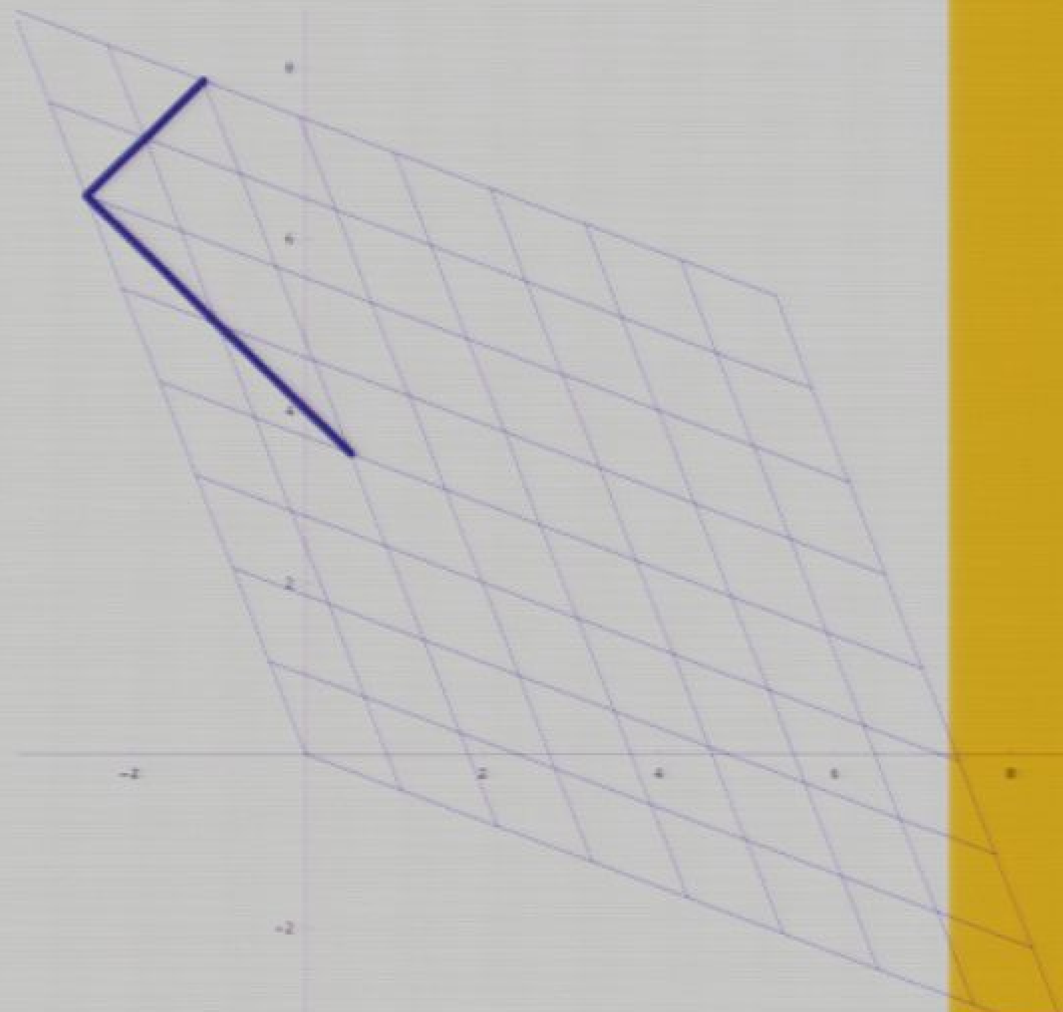
Relativity from QT

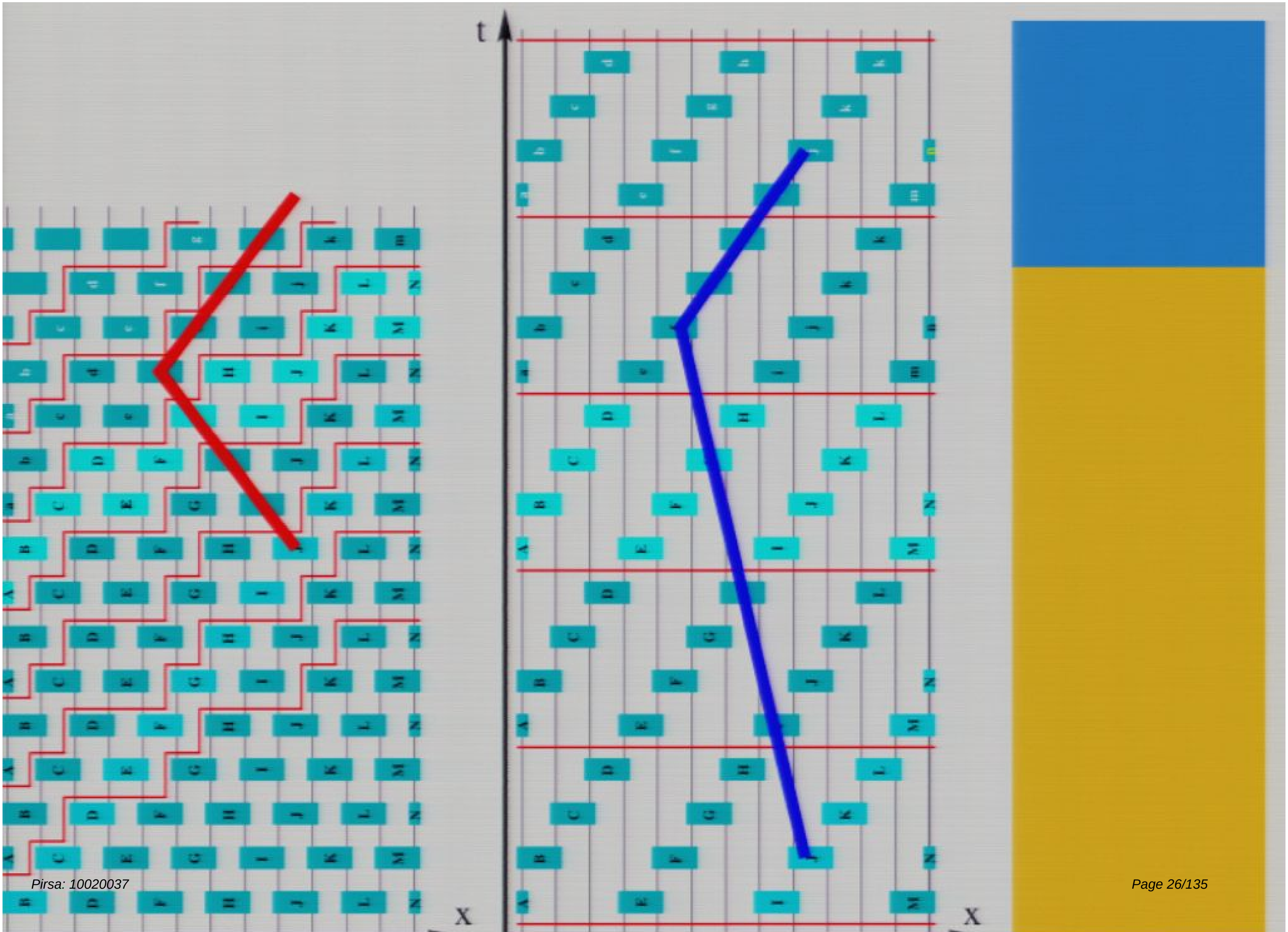




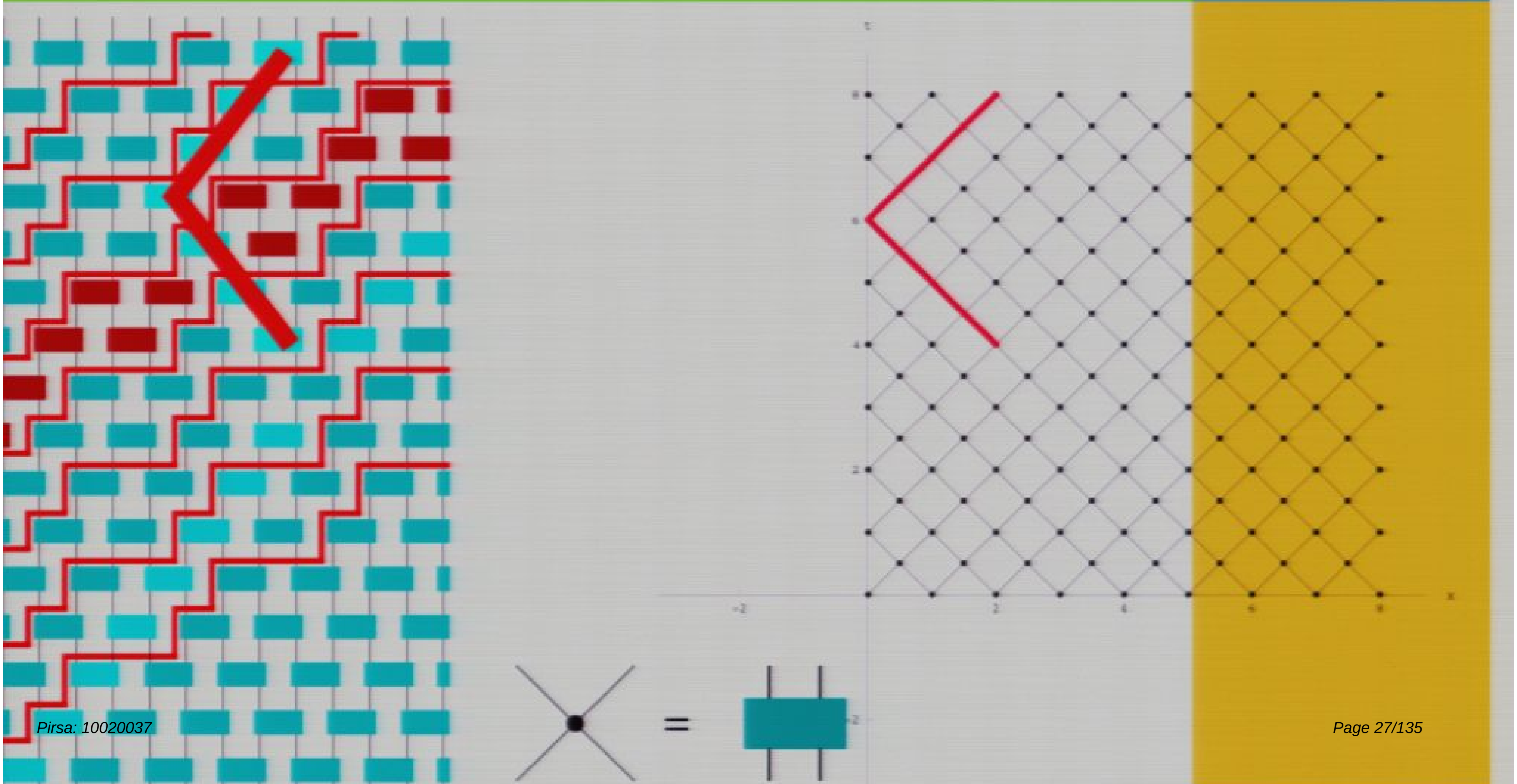
Relativity from QT

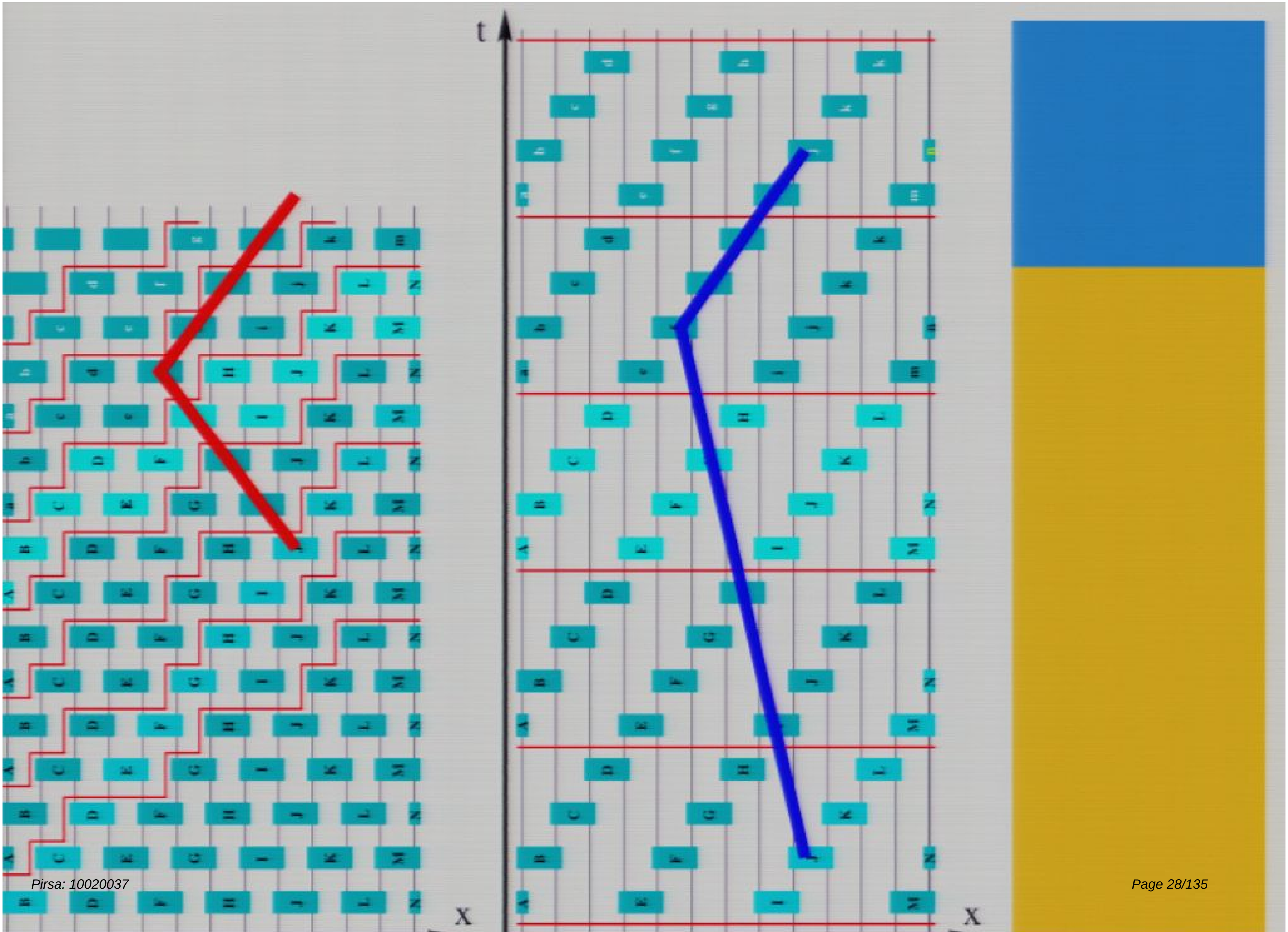




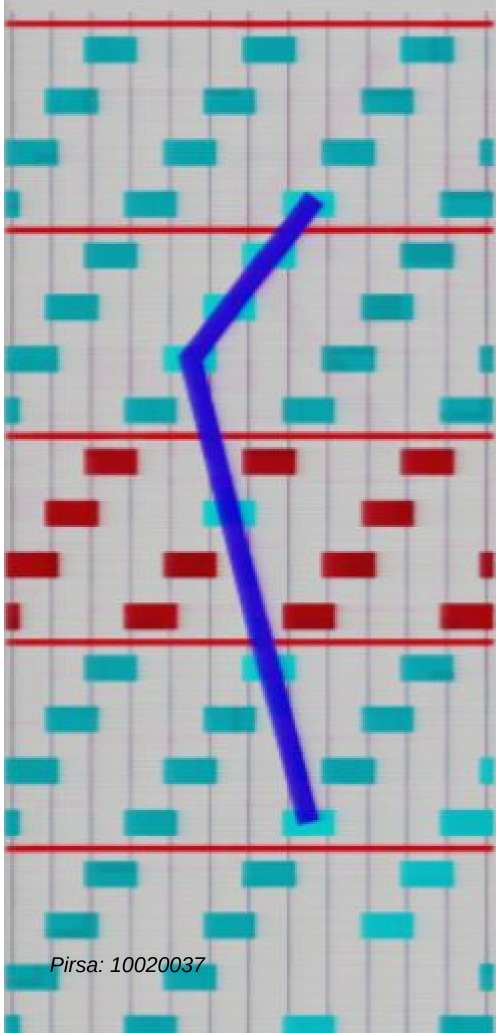

t
x
x

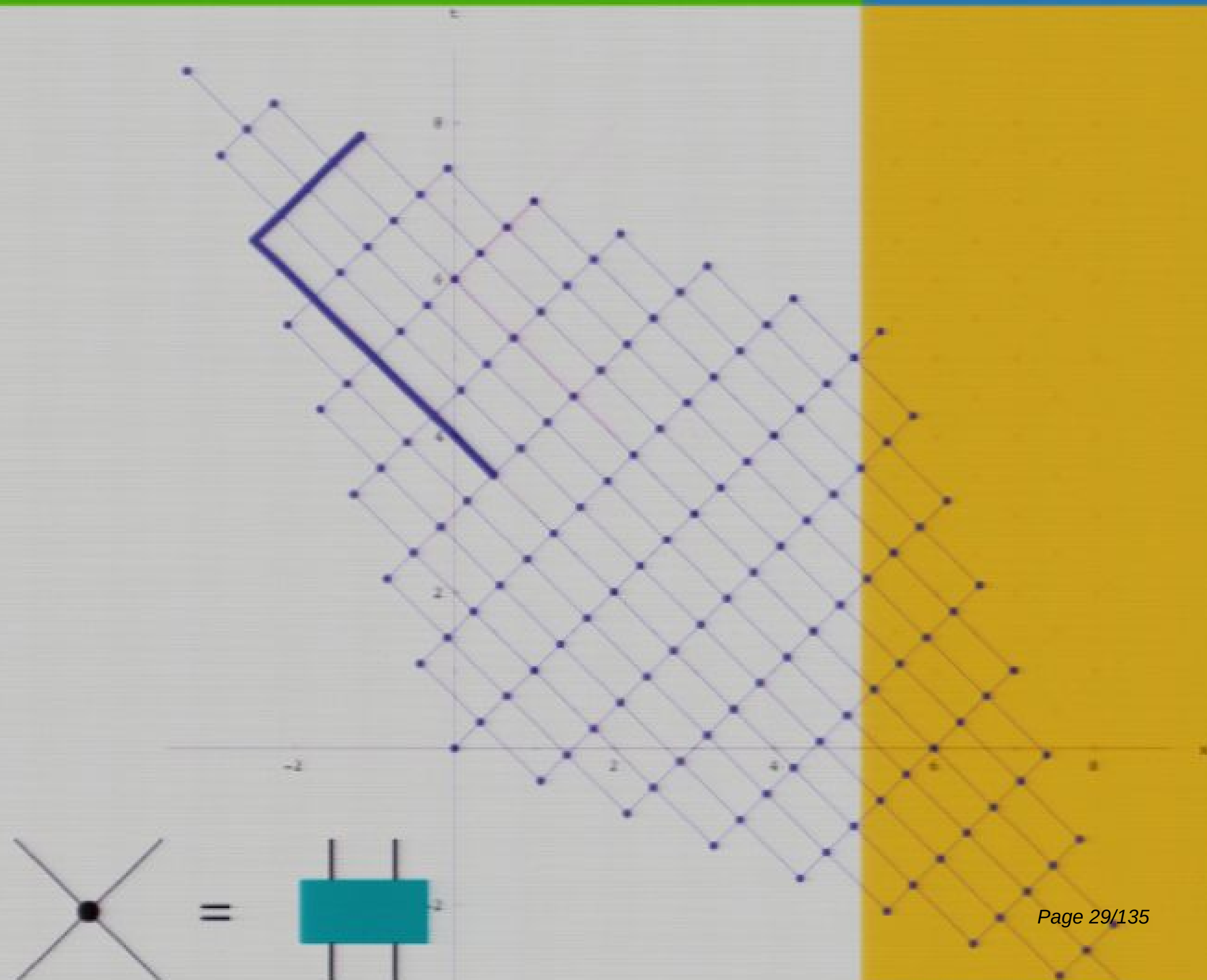
Relativity from QT




t
X
X

Relativity from QT





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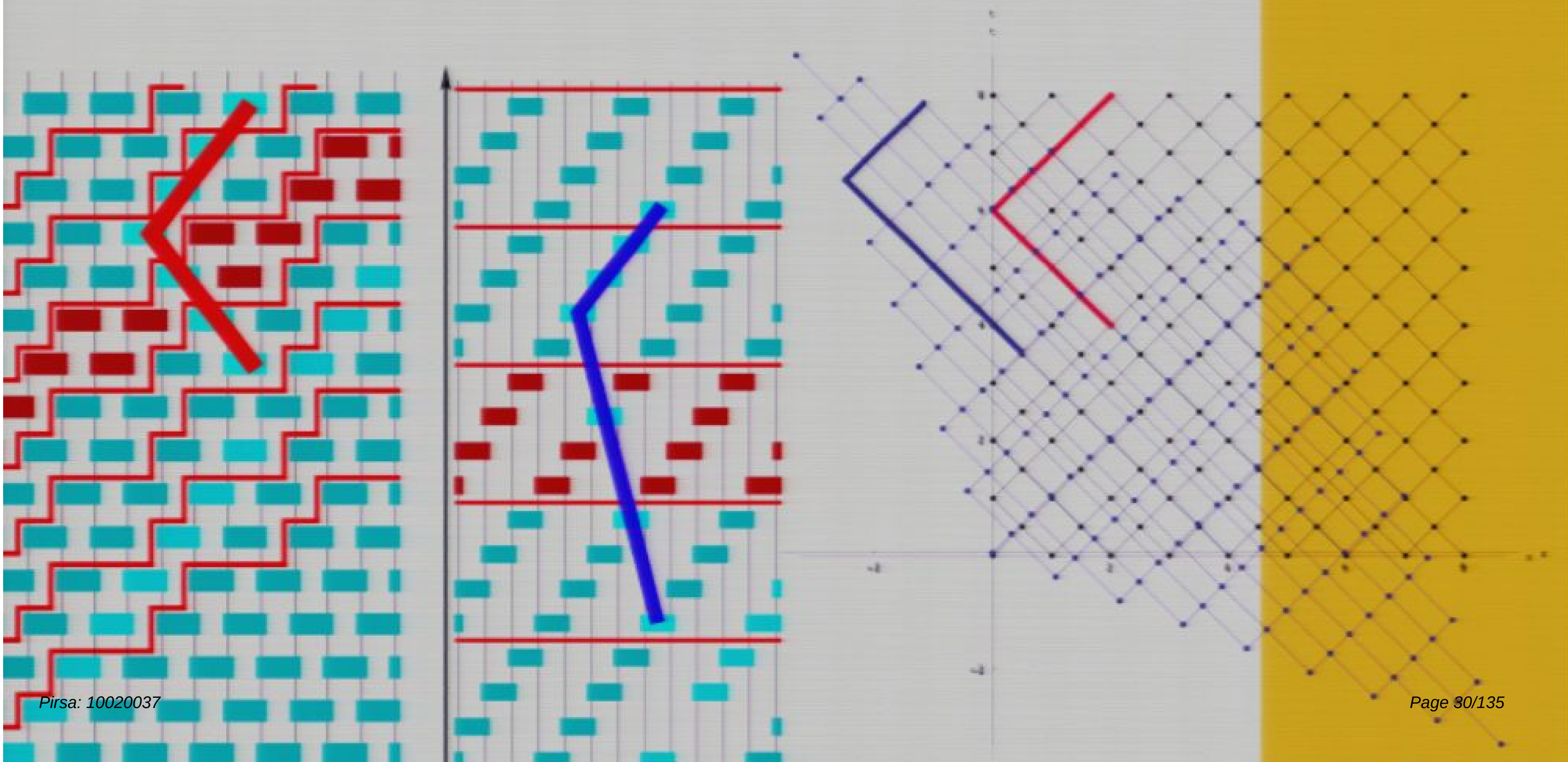

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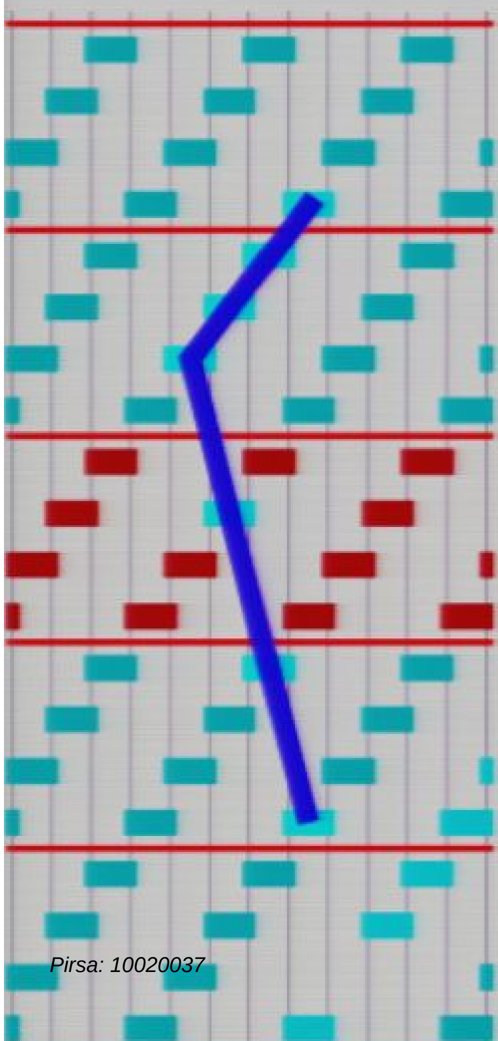

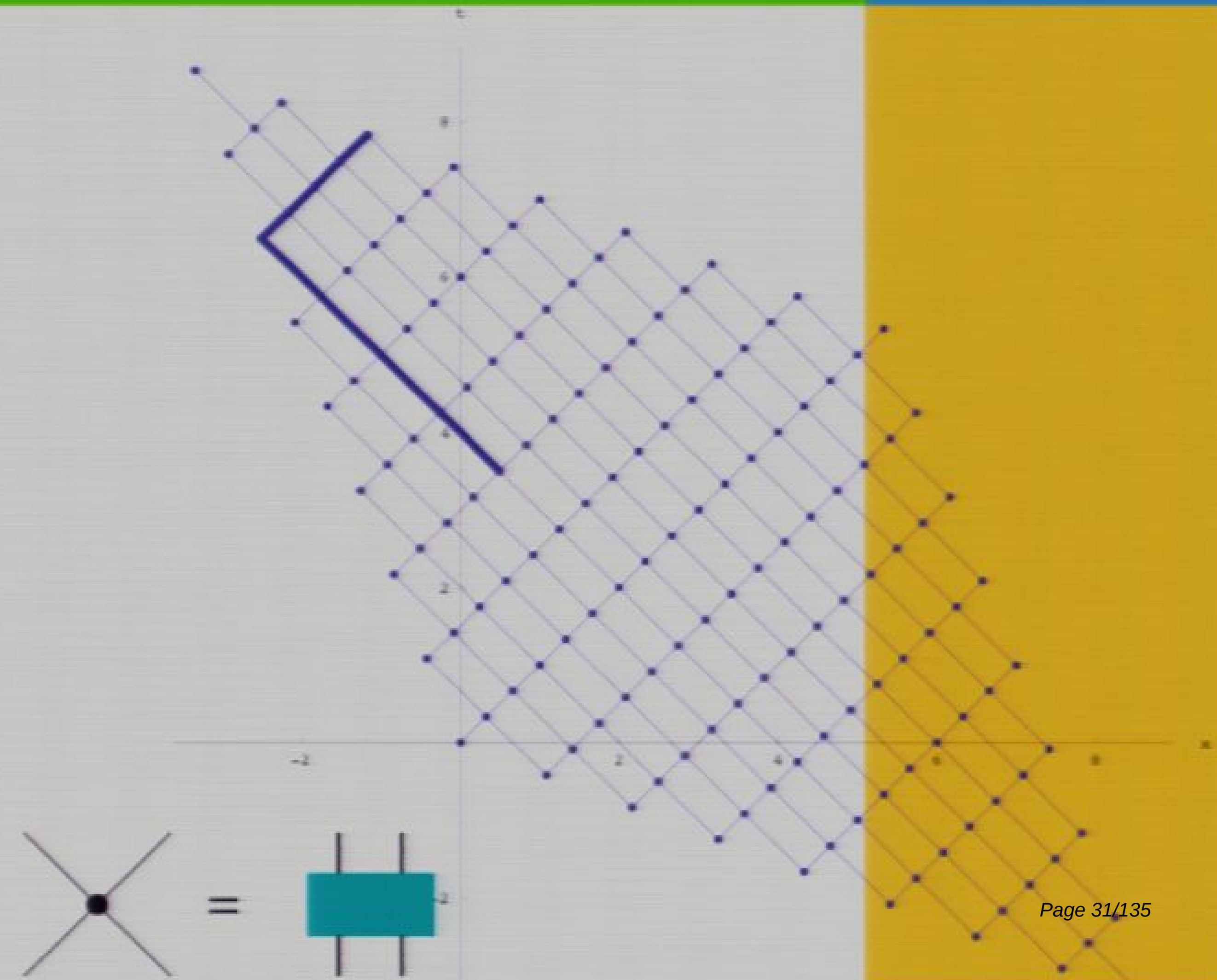

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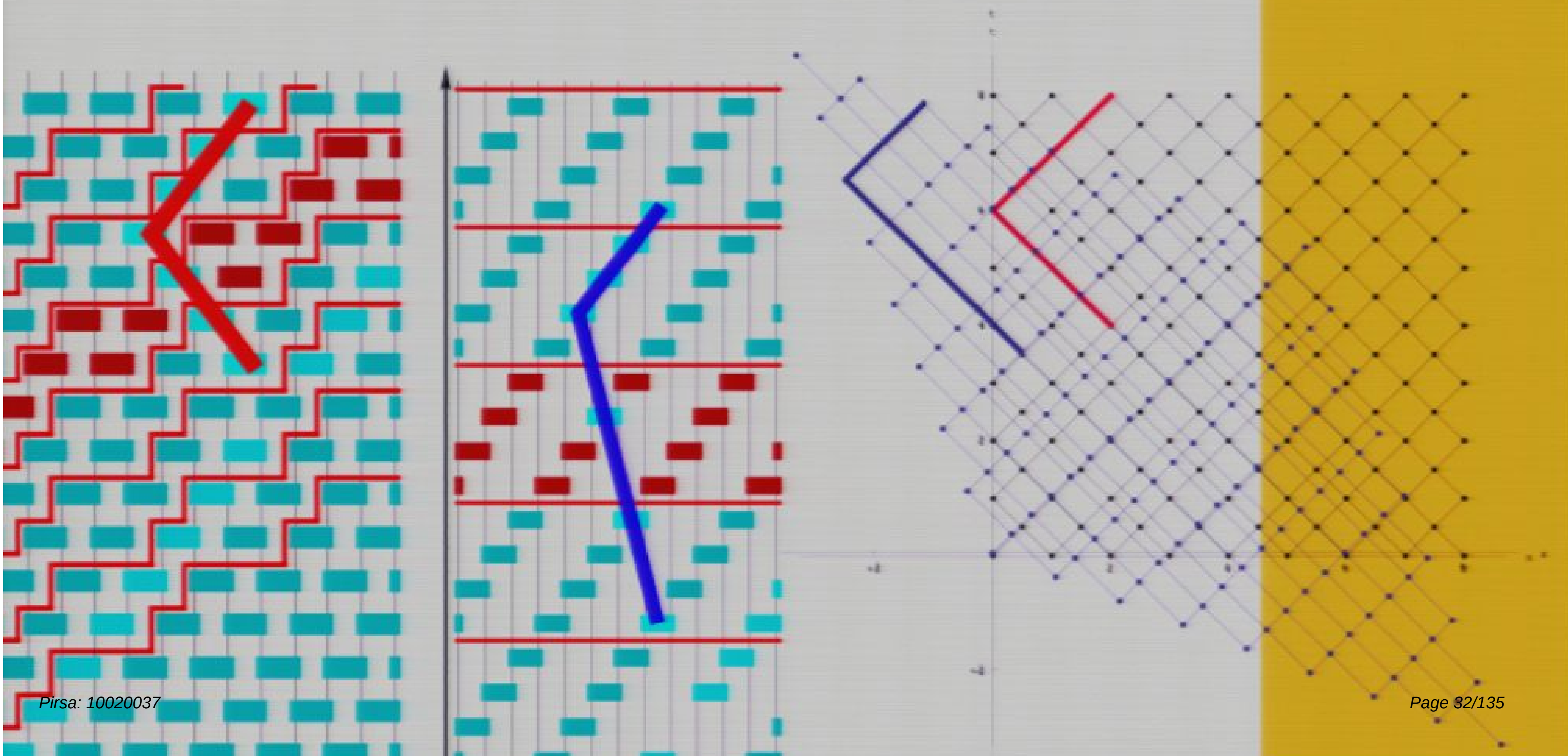
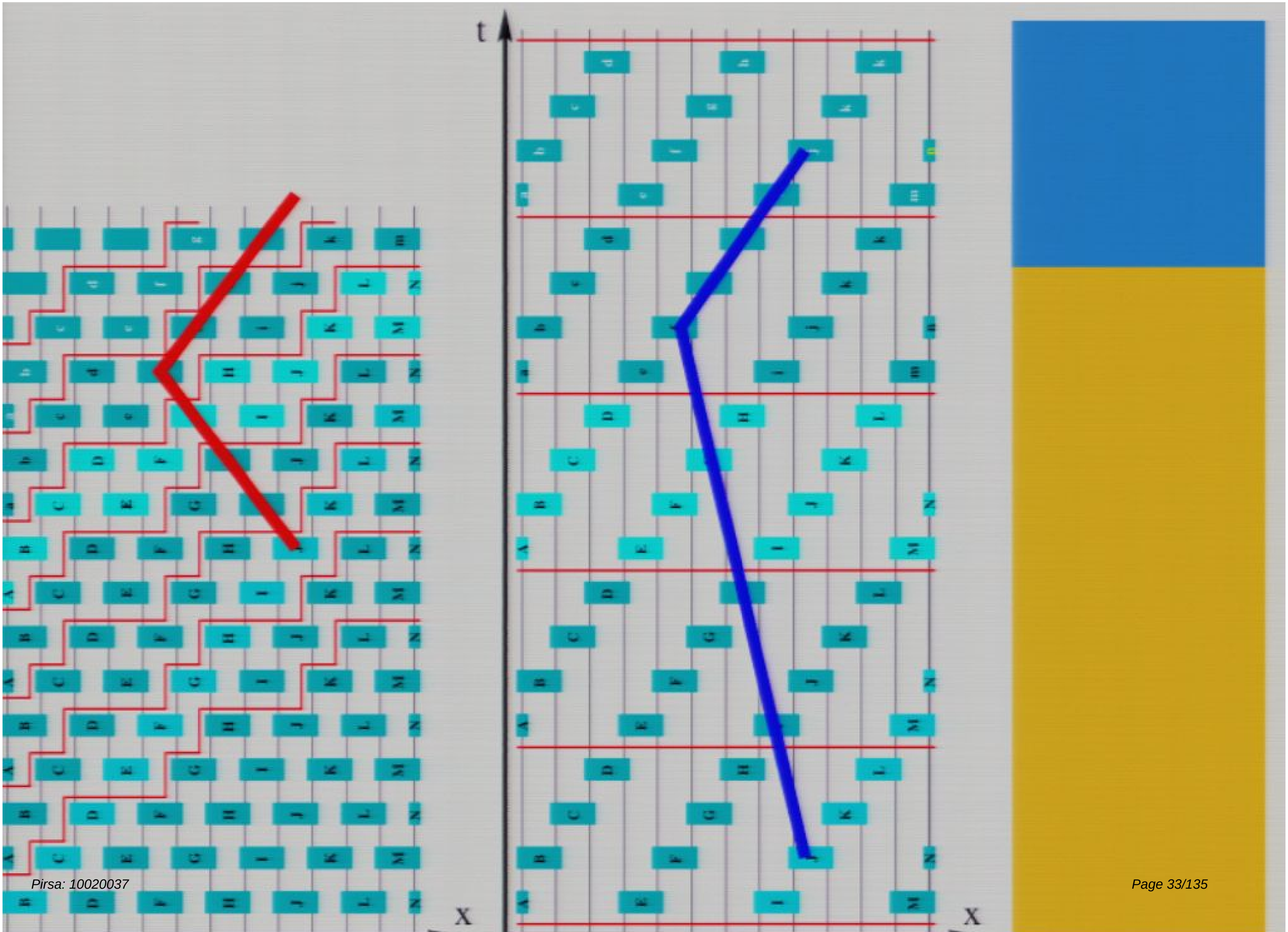
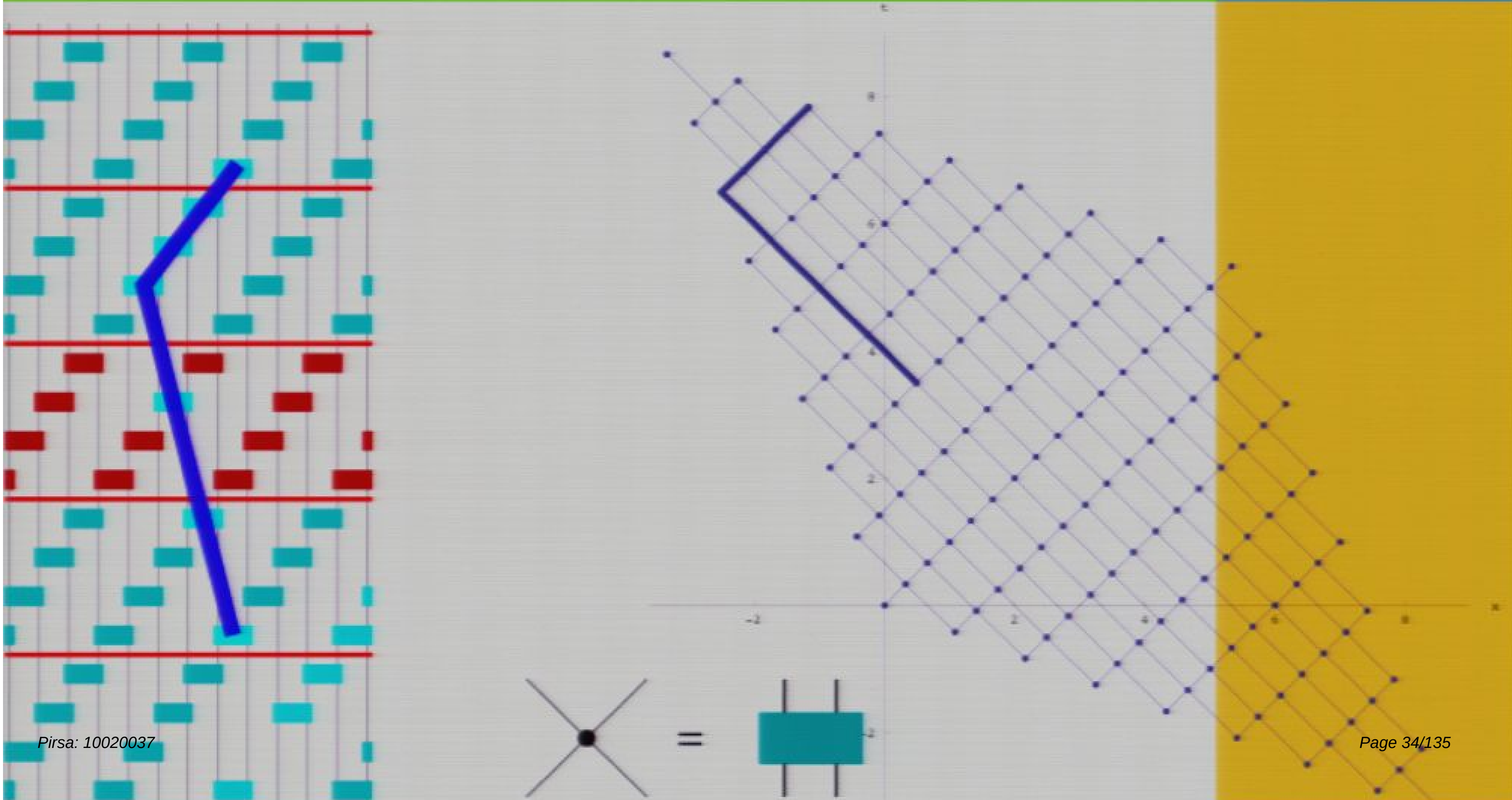



t
x
x

Relativity from QT



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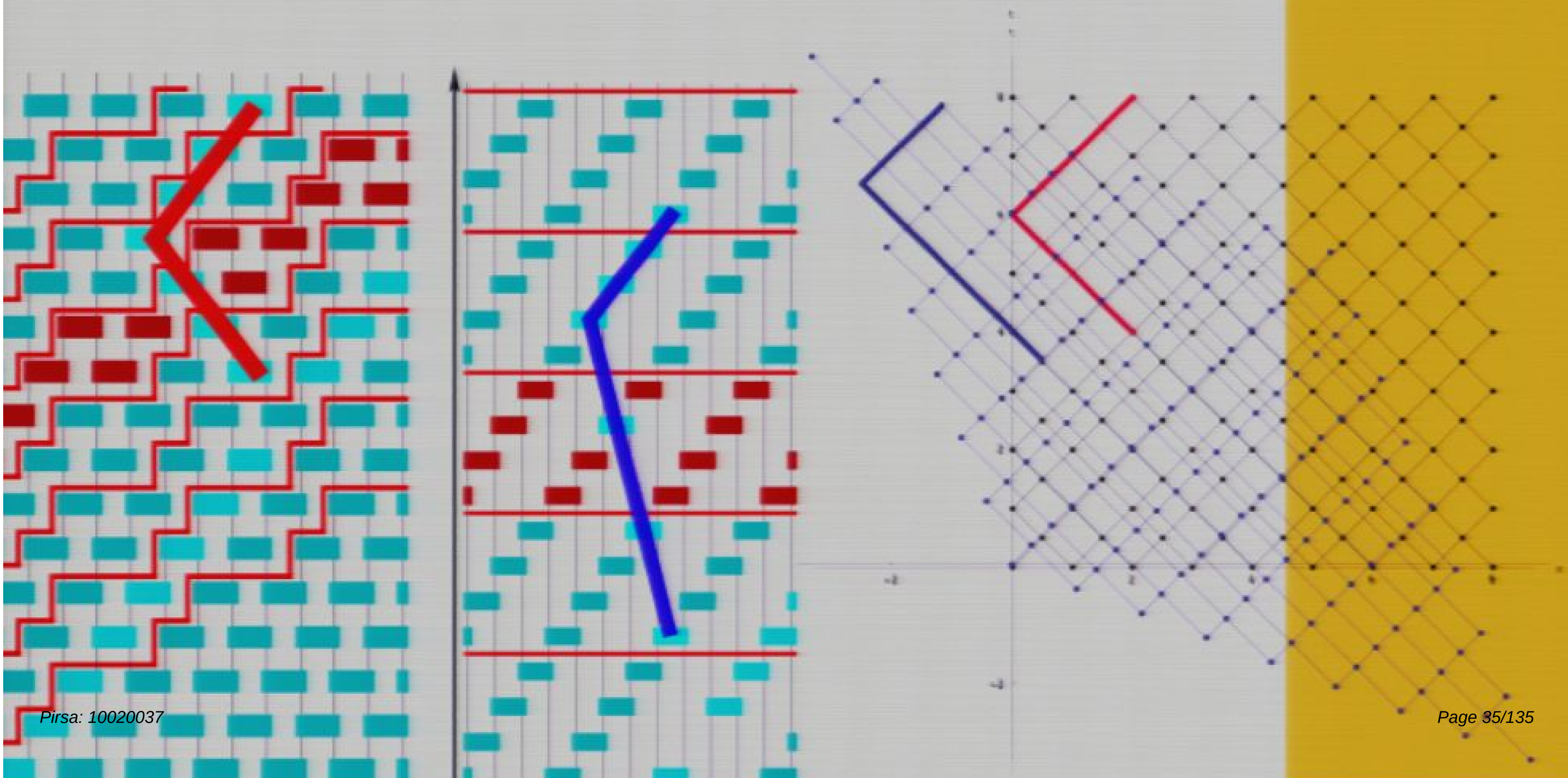
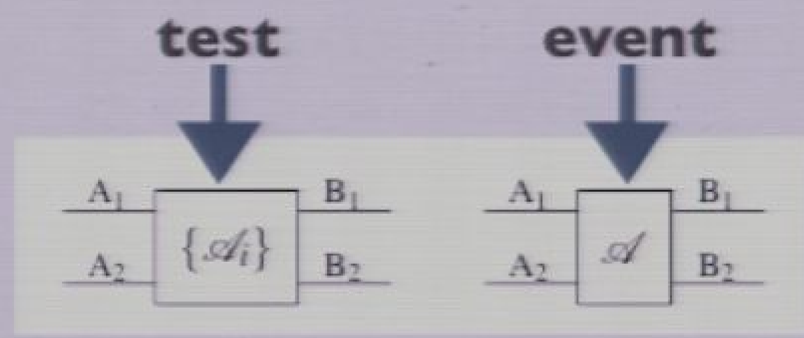
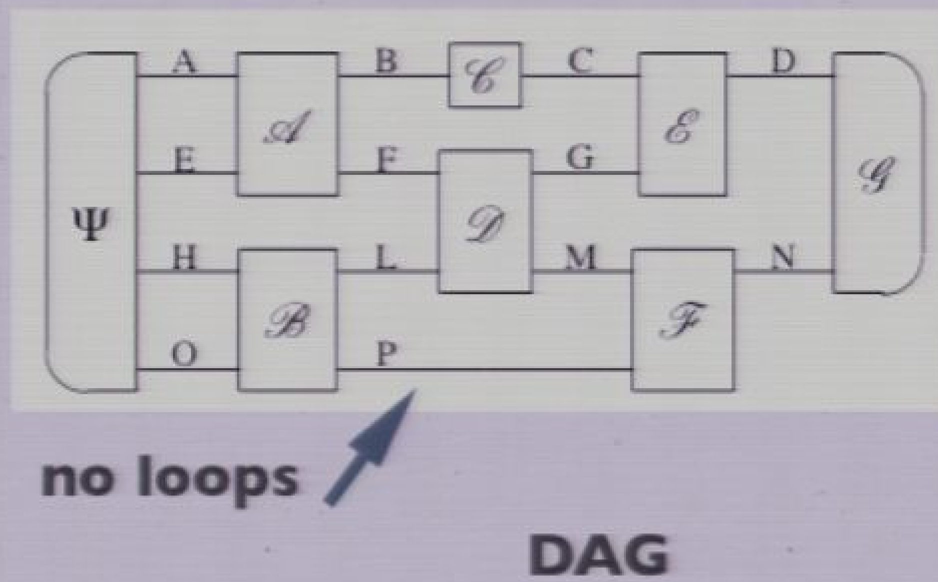


WE GOT SR FROM PURE CAUSALITY!

The Operational Framework

- **Operational theory:** collection of systems closed under parallel composition, and of tests closed under parallel/sequential composition and under randomization.
- **Probabilistic operational theory:** every test from the trivial system to the trivial system is associated to a probability distribution of outcomes.

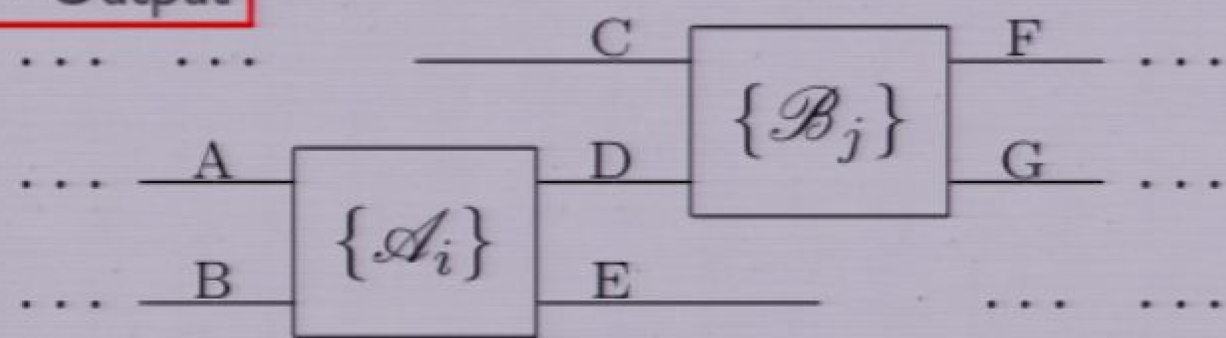




Causal probabilistic theories

Input → Output

DAG



A theory is *causal*, if for any two tests and that are connected (without loops) the marginal probability of the input event is independent on the choice of the output test, whereas, viceversa the marginal probability of the output event generally depends on the choice of the input test.

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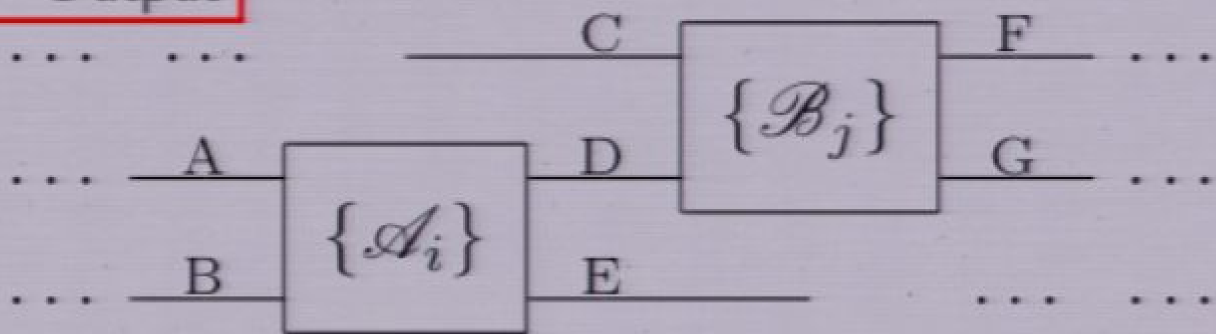

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Thm. A theory is causal iff the deterministic effect is unique for each system.

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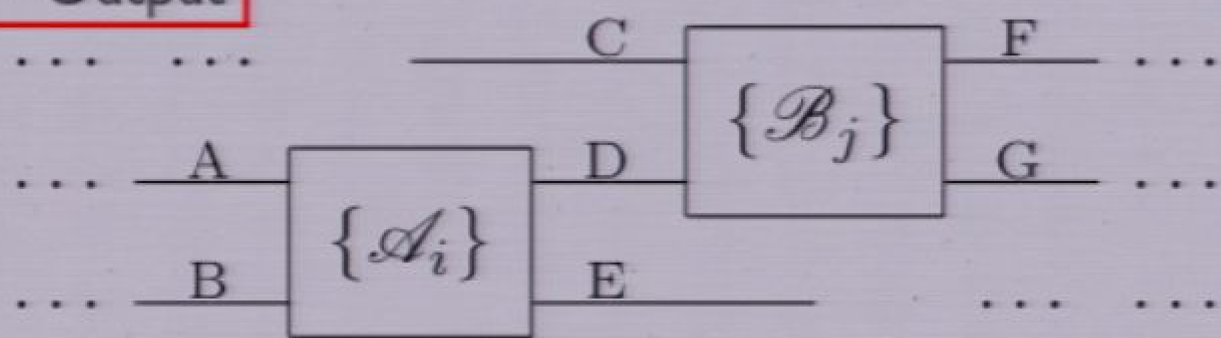

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Thm. A theory is causal iff the deterministic effect is unique for each system.

Thm. A theory is causal iff the normalization of states is a multiplication by a scalar.

Wittgenstein-ism

1 The world is all that is the case.

1.1 The world is the totality of facts, not of things.

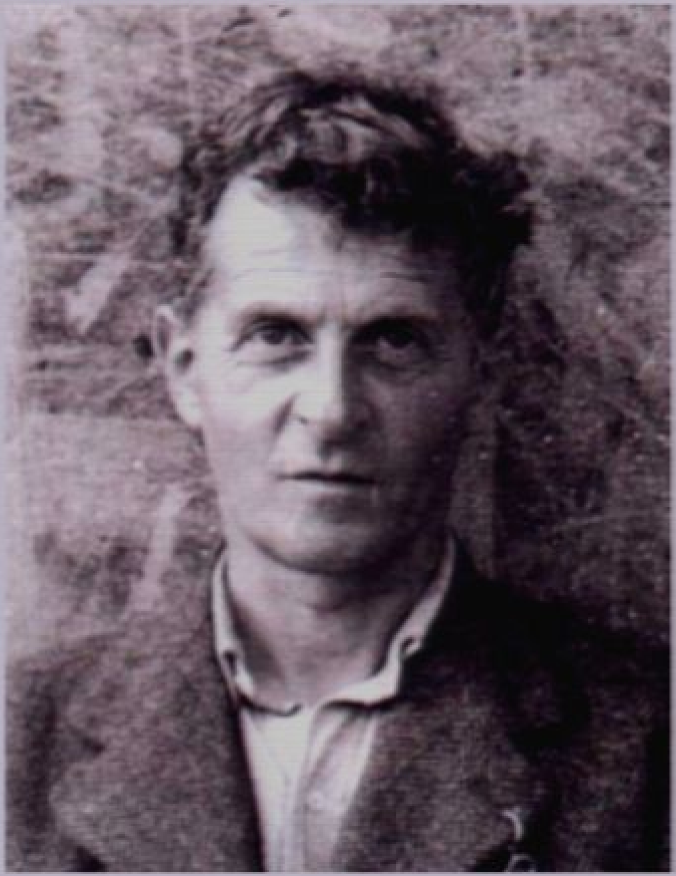
1.11 The world is determined by the facts, and by their being all the facts.

1.12 For the totality of facts determines what is the case, and also whatever is not the case.

1.13 The facts in logical space are the world.

1.2 The world divides into facts.

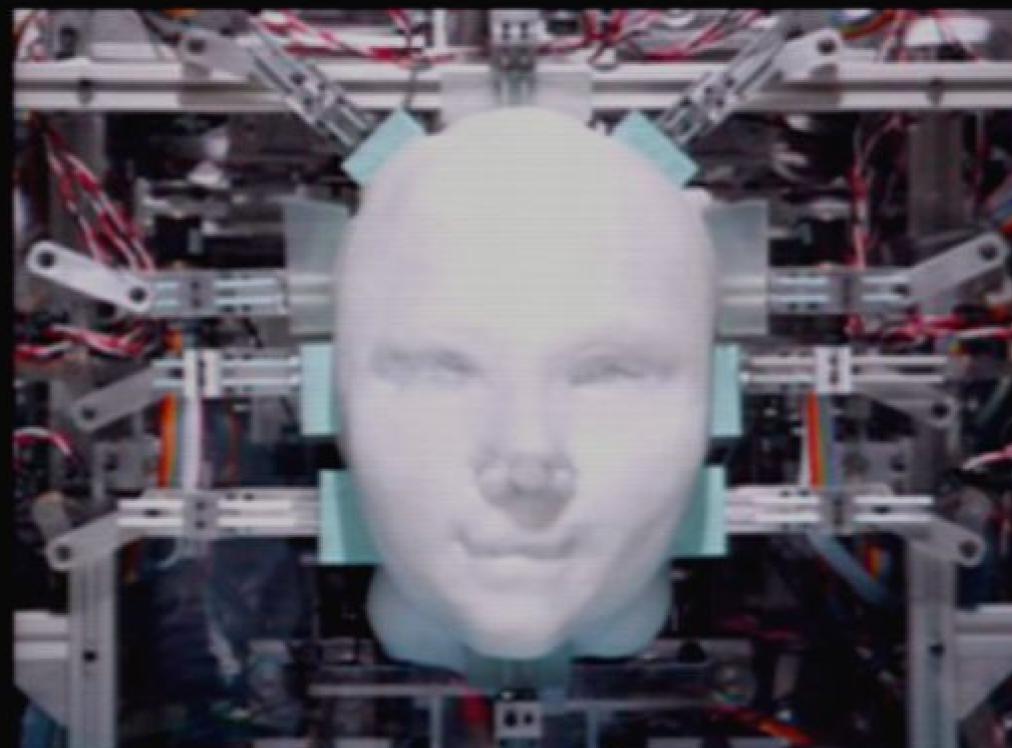
1.21 Each item can be the case or not the case while everything else remains the same.

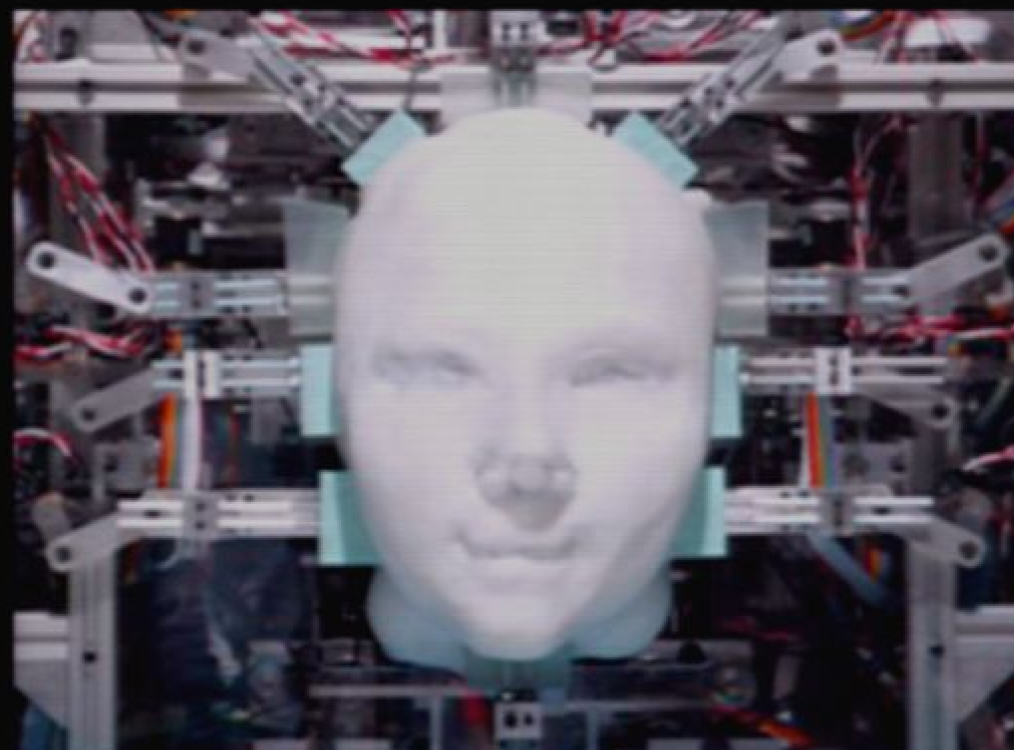


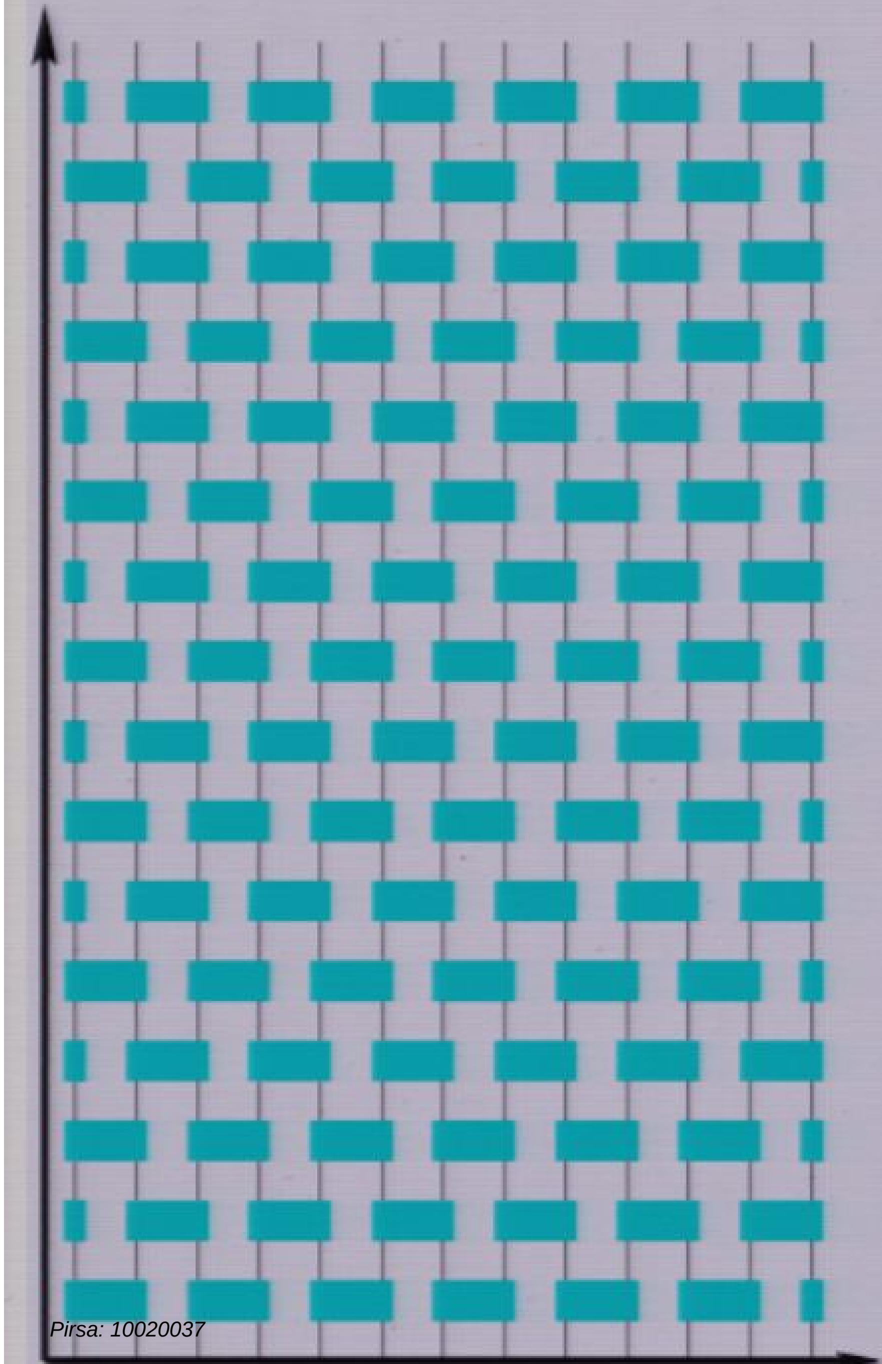
My Brief History of Space-Time

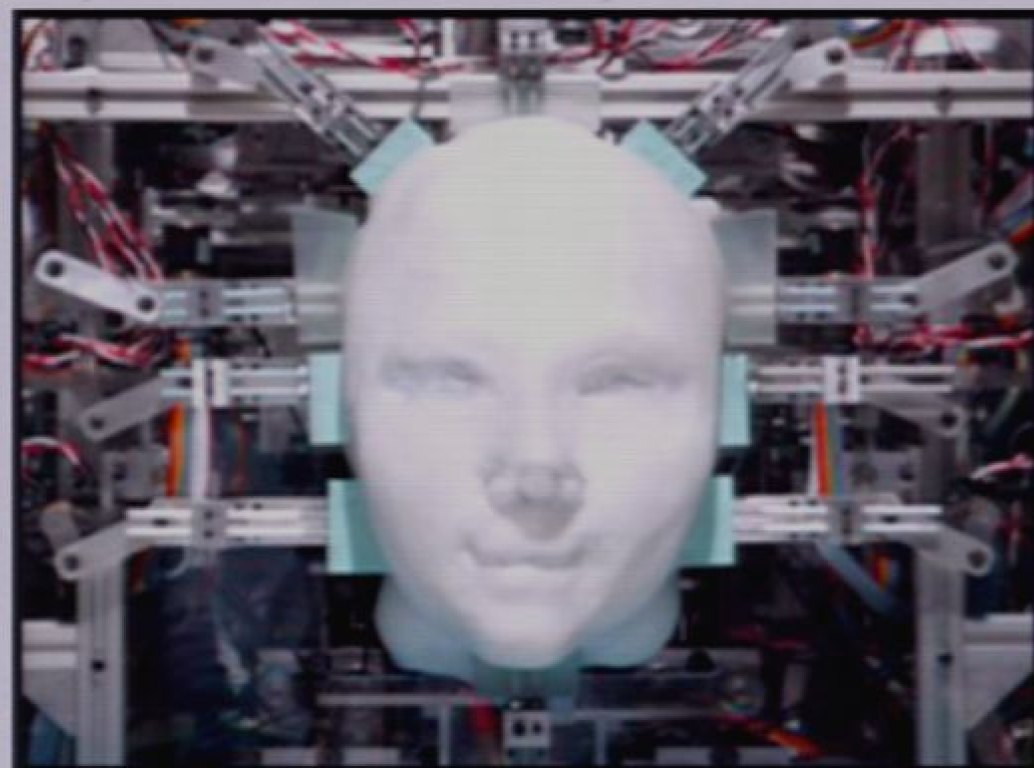
My Brief History of Space-Time

- At the beginning there were only events ...
  - Then the Man devised causal connections between events
    - He modeled the causal connections in a unified framework which is space-









Quantum Computational Field Theory (QCFT)

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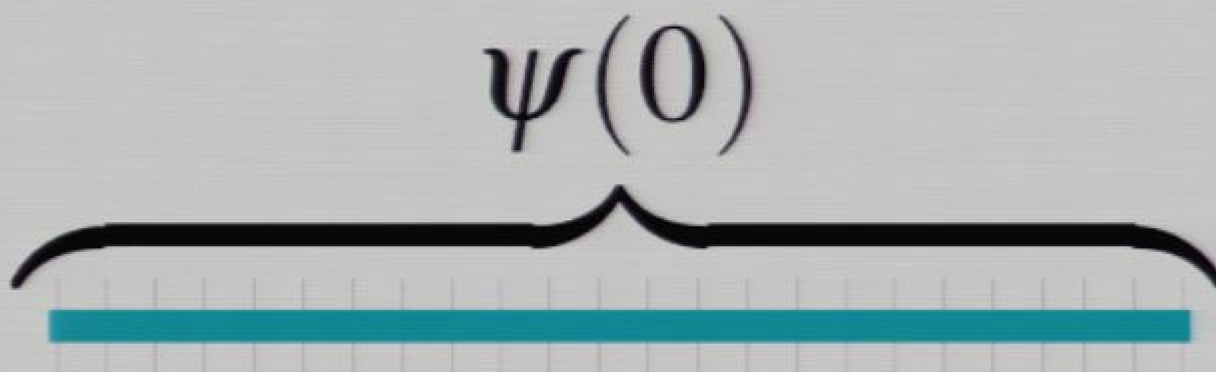
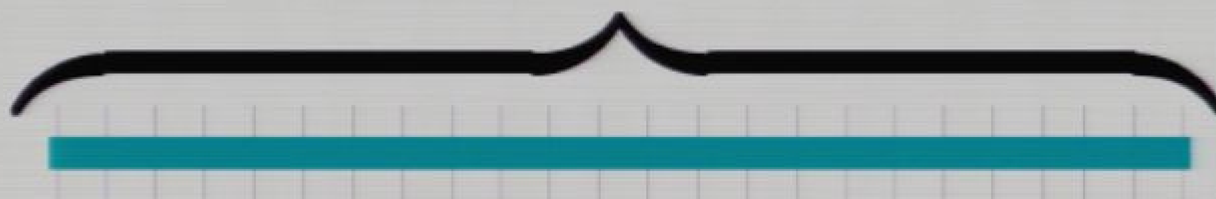


Quantum Computational Field Theory (QCFT)

$$\psi(0)$$



$$H = \sum_{\langle i,j \rangle} H_{i,j}$$

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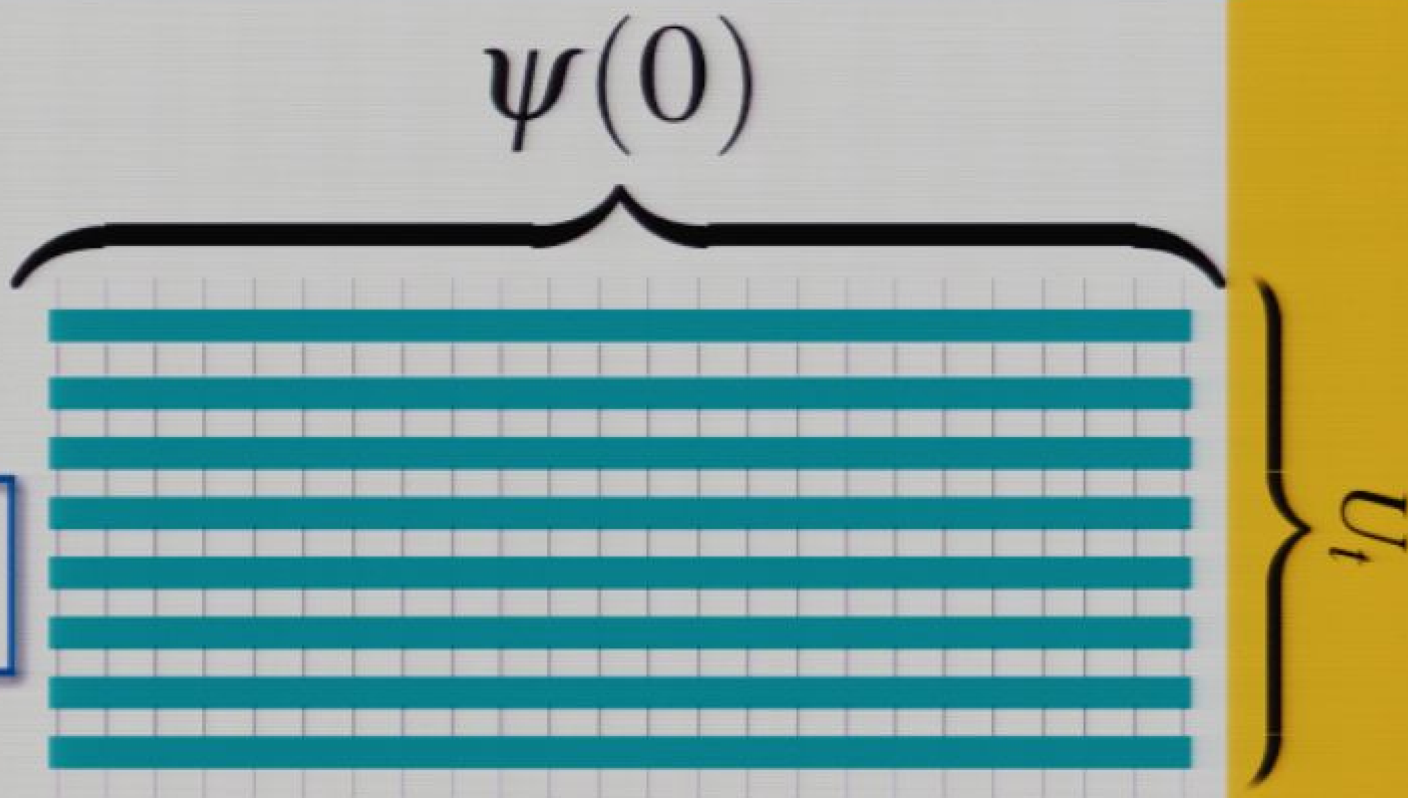

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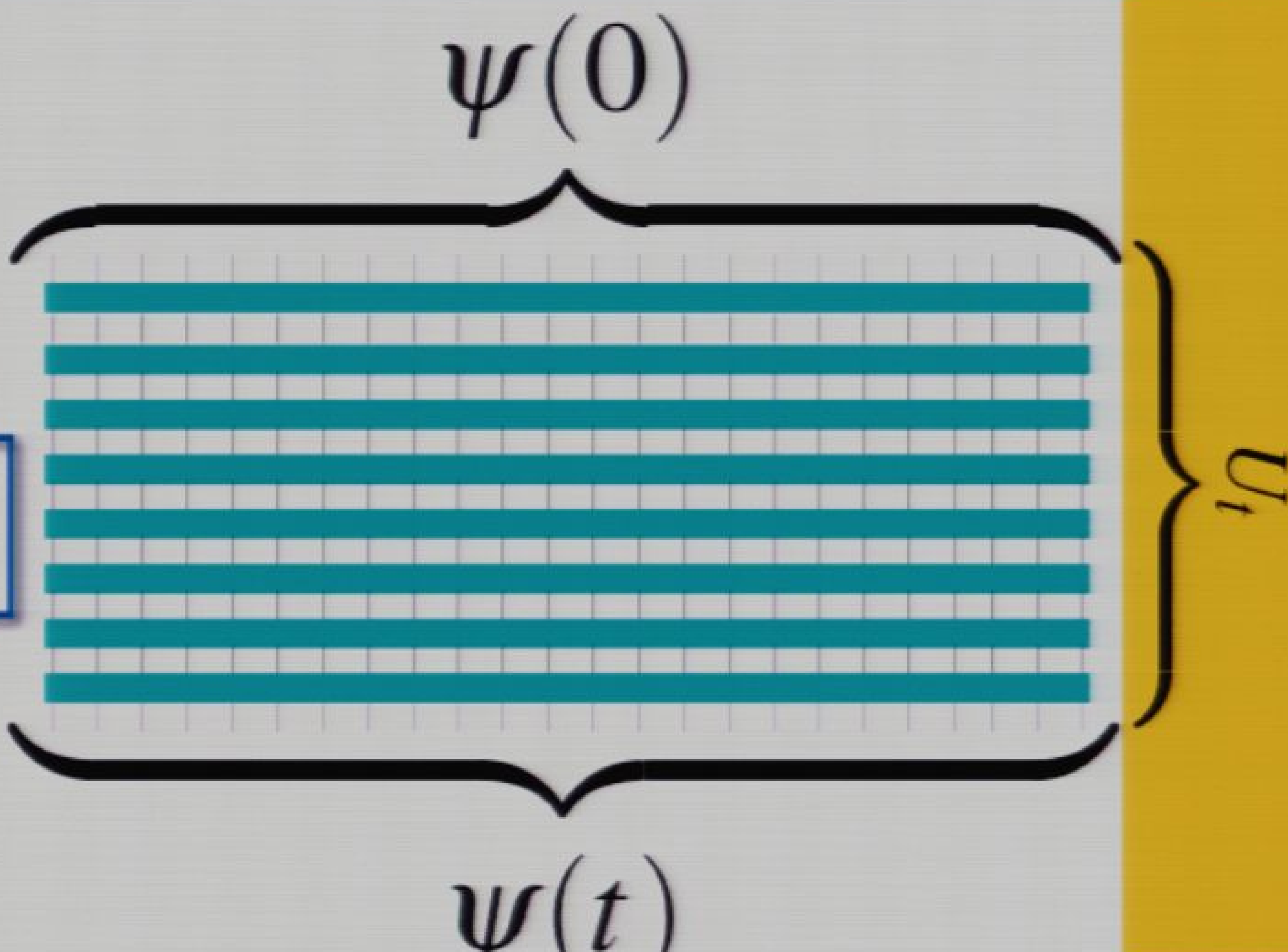
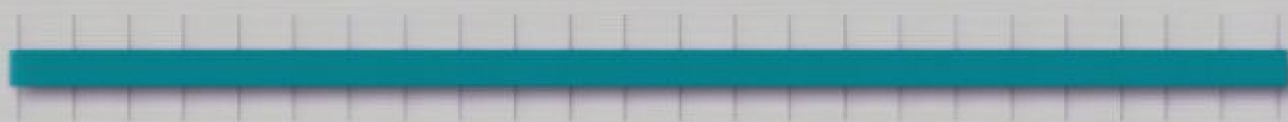


$$H = \sum_{\langle i,j \rangle} H_{i,j}$$

QCFT

p nn translational-invariant "Hamiltonian"



Trotter-ization of H

QCFT

Trotter-ization of H

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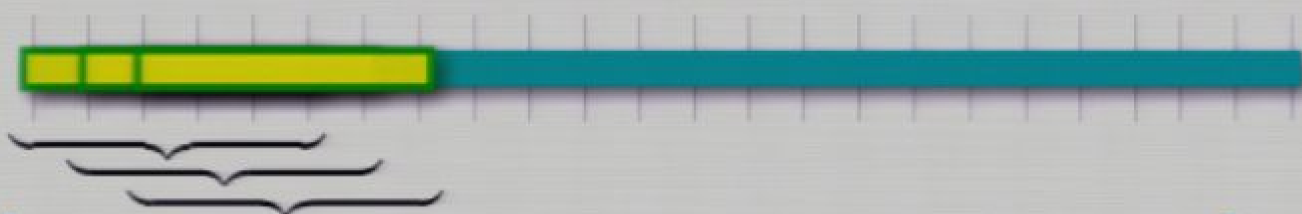

$$H = \sum_{k=0}^{p-1} H^{(k)}, \quad H^{(k)} = \sum_{i=-N_x}^{N_x} H_i^{(k)}$$

QCFT

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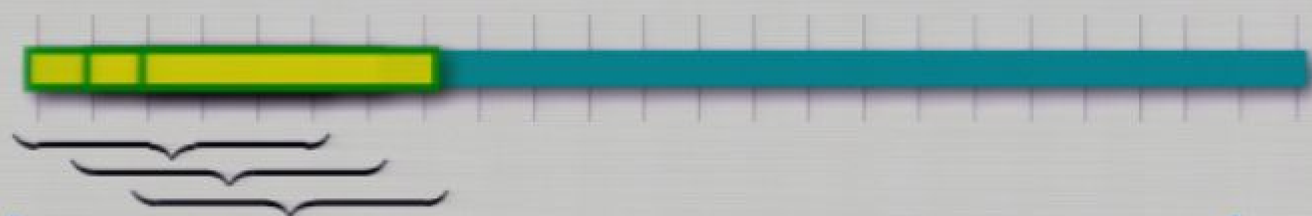

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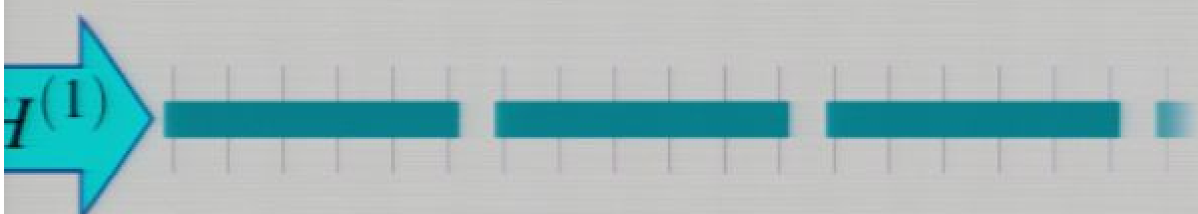

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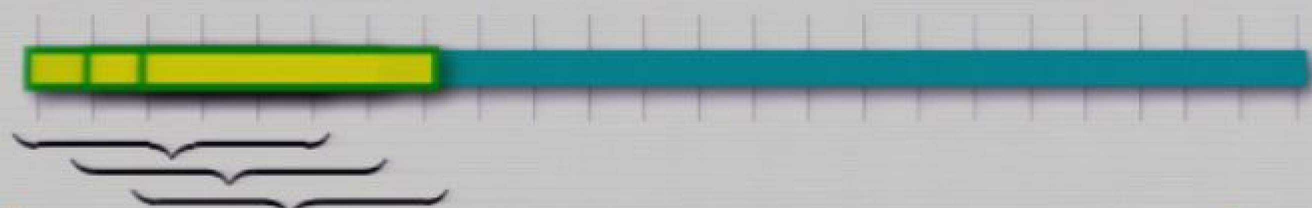

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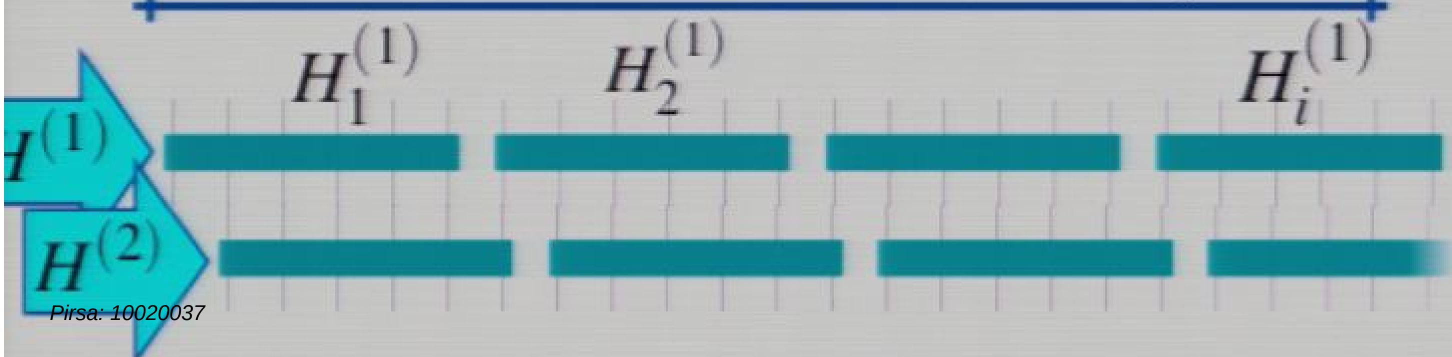

Trotter-ization of H

QCFT

Trotter-ization of H

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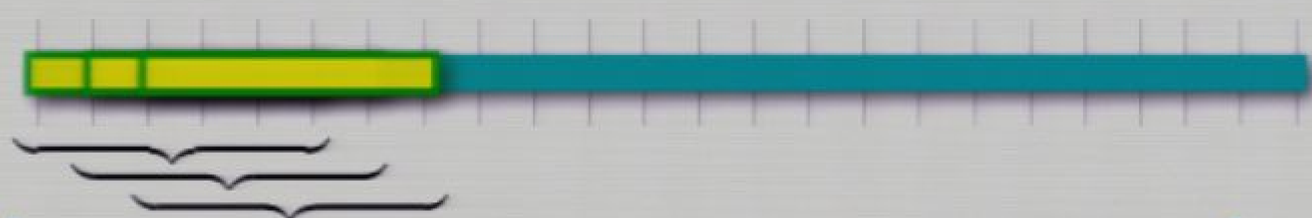

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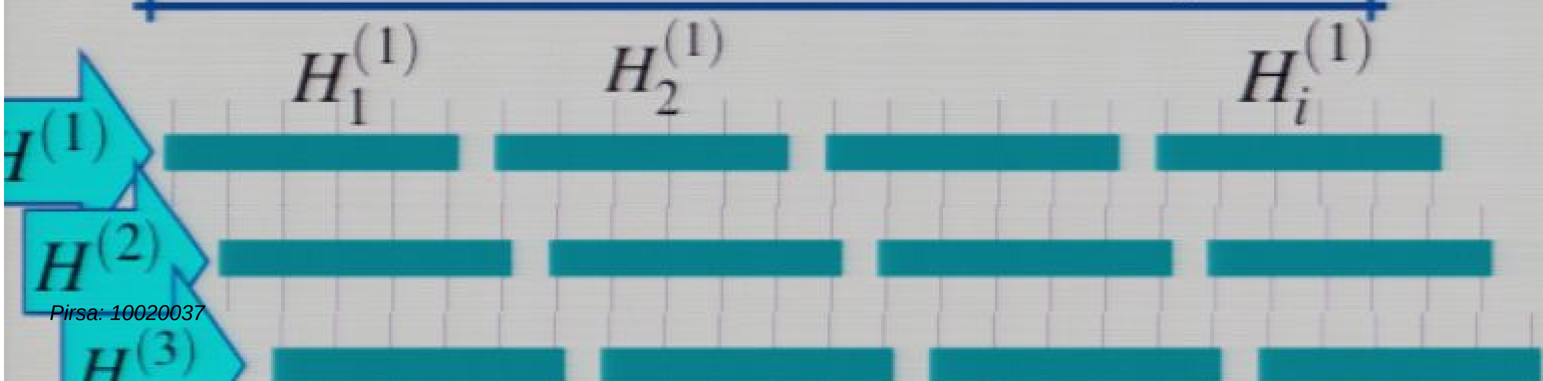
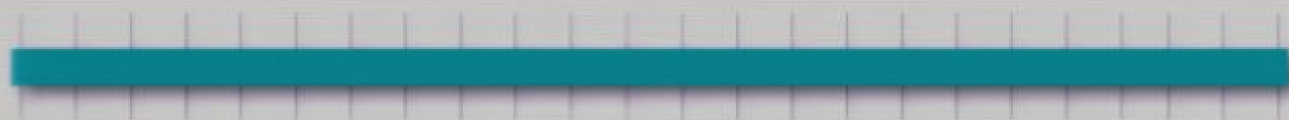
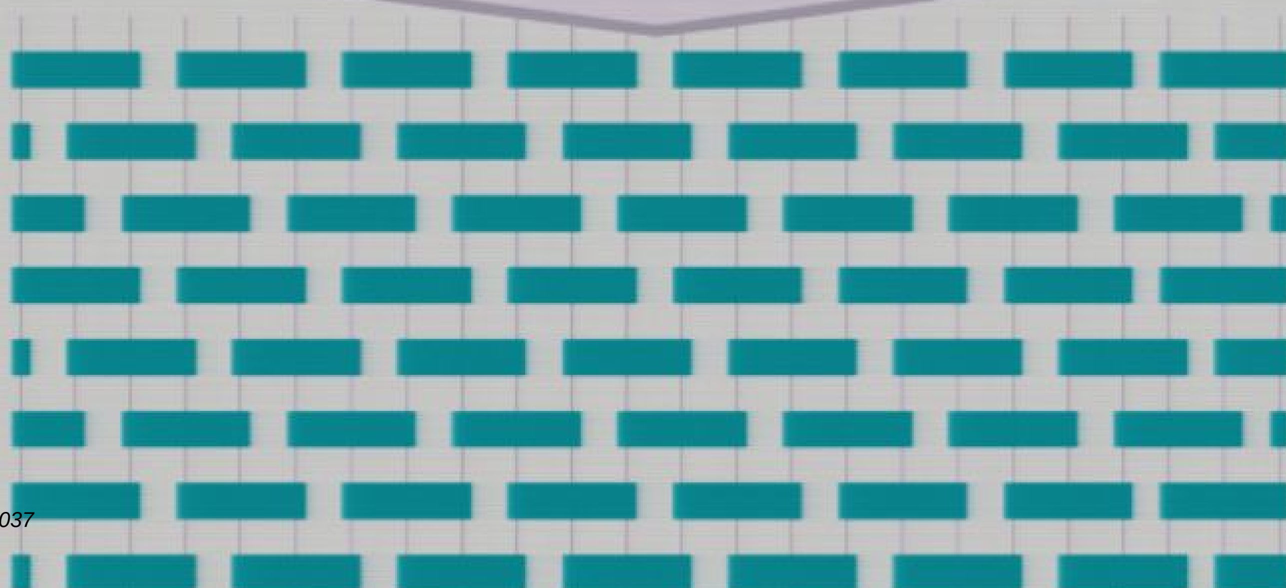


QCFT



$$\lim_{N\to\infty}\left(e^{-i\frac{\phi_t}{N}H^{(0)}}e^{-i\frac{\phi_t}{N}H^{(1)}}\right)^N = e^{-i\phi_t H}$$



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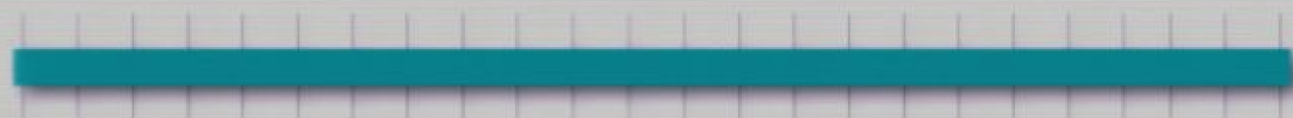

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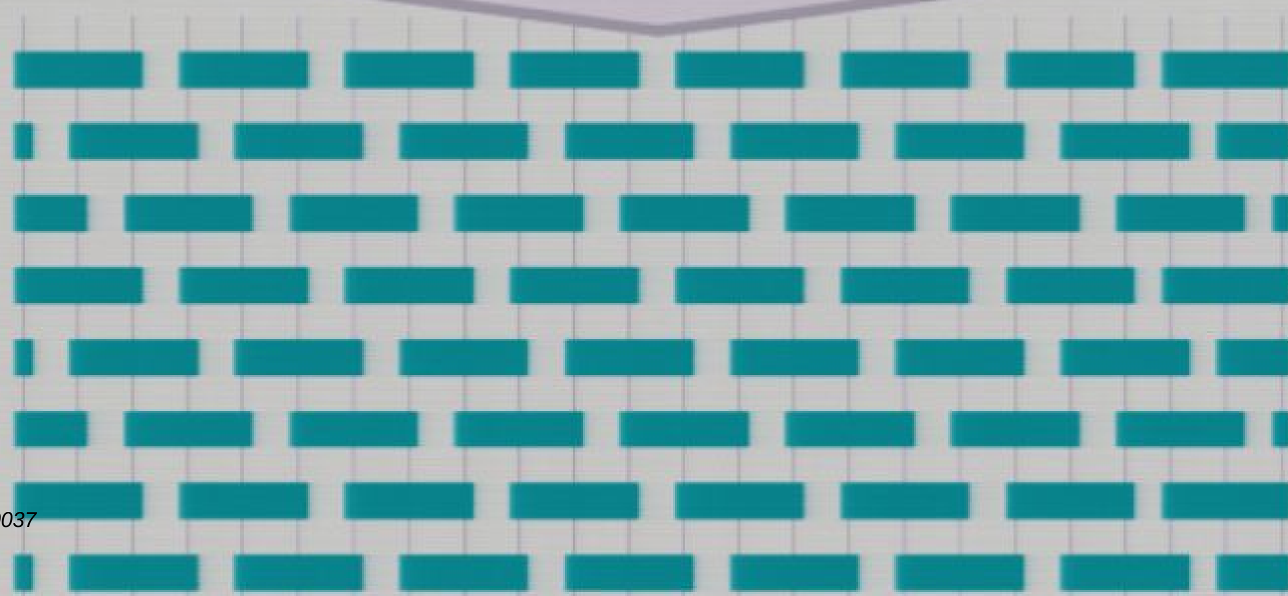
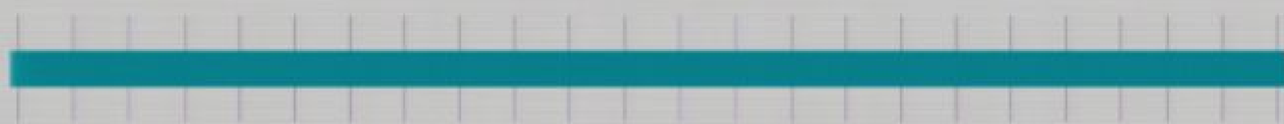


Trotter-ization of H

QCFT

H



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$= 0, \quad [H^{(l}$

QCFT

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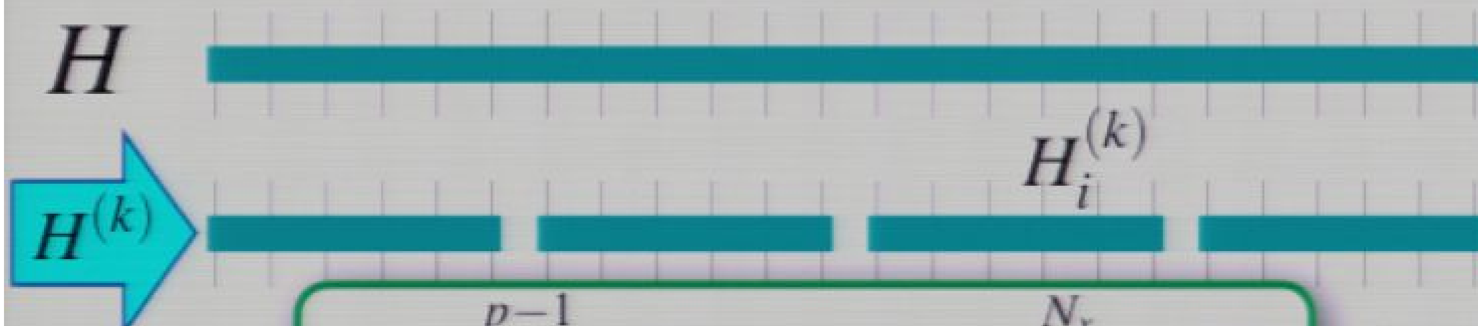

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Suzuki's bound

QCFT

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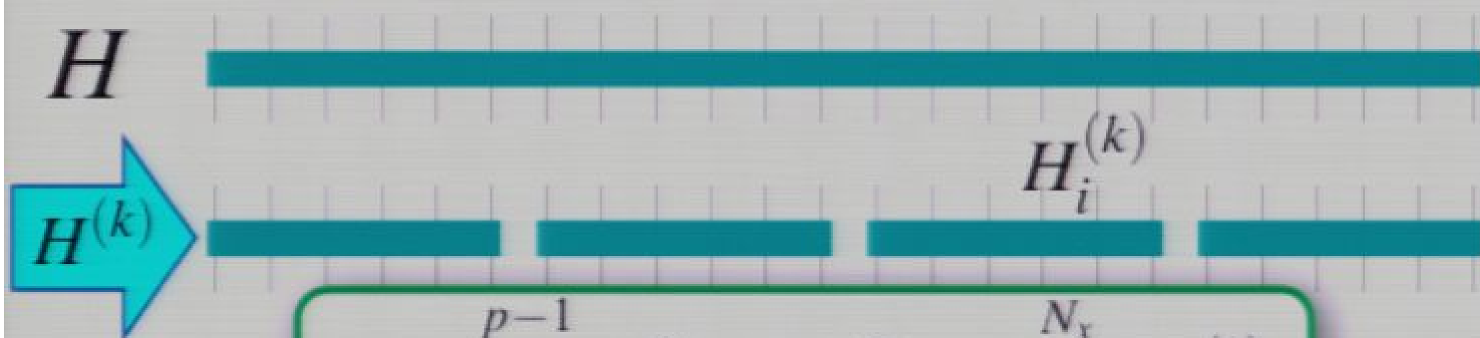

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$$\left\| \exp\left(\sum_{k=0}^{p-1} H^{(k)}\right) - \left[\prod_{k=0}^{p-1} \exp\left(\frac{H^{(k)}}{n}\right)\right]^n \right\| \leqslant \frac{2}{n}\left(\sum_{i=0}^{p-1} \|H^{(k)}\|\right)^2 \exp\left(\frac{n+2}{n}\sum_{k=0}^{p-1}\|H^{(k)}\|\right)$$

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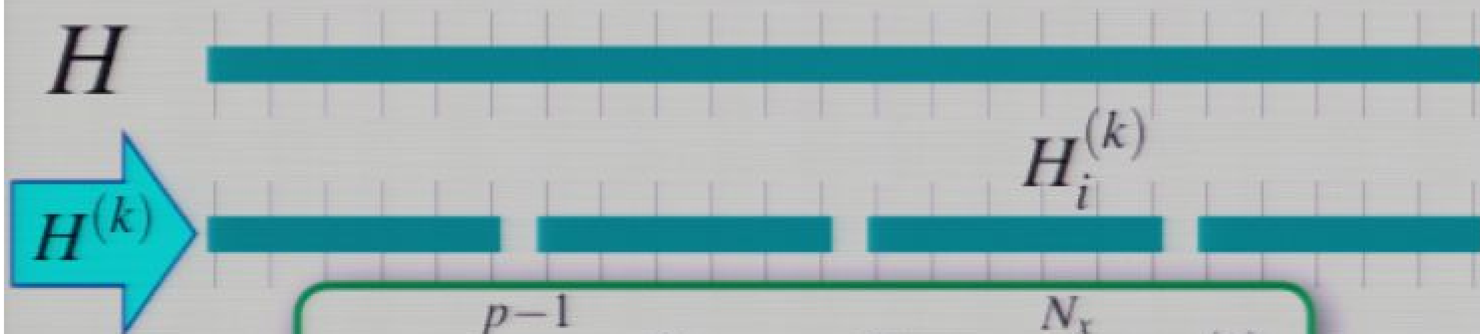
QCFT



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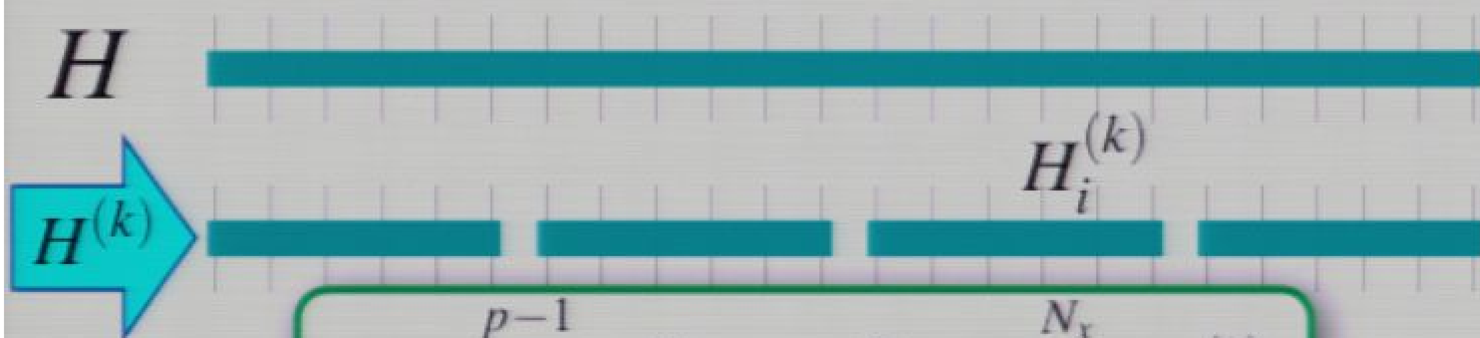

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Trotter-ization of H

SIMULATING QFT

Simple scalar fields in 1 space dimension

SIMULATING QFT

Simple scalar fields in 1 space dimension

★ ★ ★ ★ ★ ★ ★ ★

a infinitesimal space-granularity (minimal in principle discrimination between independent events);

$\phi(x)$ field, operator function of space (evolving in time); we will describe it by the set of operators $\phi_n := a^{\frac{1}{2}}\phi(na)$

SIMULATING QFT

Simple scalar fields in 1 space dimension

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SIMULATING QFT

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Simplest equal-time microcausality:

Fermion: ψ $\{\psi_n, \psi_m\} = \delta_{nm}$ (Dirac)

Boson: φ $[\varphi_n, \varphi_m] = \delta_{nm}$ (Newton-Wigner)

SIMULATING QFT

Simple scalar fields in 1 space dimension

Time evolution: $\phi(t) = U_t \phi(0) U_t^\dagger$

$$U_t = \exp\left(-\frac{i}{\hbar} t\hbar\omega H\right) = \exp(-2\pi i N_T H)$$

H: adimensional Hamiltonian

$$N_T = \frac{t}{T} = \frac{\omega t}{2\pi} = \frac{\phi_t}{2\pi}$$

SIMULATING QFT

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$$i\hbar\partial_t \phi = [\hbar\omega H, \phi]$$

SIMULATING QFT

Simple scalar fields in 1 space dimension

$$H = -\frac{i}{2}\sum_n (\phi_n^\dagger \phi_{n+1} - \phi_{n+1}^\dagger \phi_n) = \frac{a}{\hbar} P$$

$$\phi_n := a^{\frac{1}{2}} \phi(na)$$

$$P = -i\hbar \int \mathrm{d}x \phi^\dagger(x) \partial_x \phi(x)$$

SIMULATING QFT

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$$[H, \phi(x)] = [H, a^{-\frac{1}{2}}\phi_n] = a^{-\frac{1}{2}}\frac{i}{2}(\phi_{n+1} - \phi_{n-1}) = ia\partial_x \phi(x)$$

$\omega a = c$ → $\Box \phi = 0$ **Klein-Gordon**

SIMULATING QFT

Simple scalar fields in 1 space dimension

★ ★ ★ ★ ★ ★ ★ ★

Trotter-ization

$$H = H^{(0)} + H^{(1)}, \quad H^{(k)} = -\frac{i}{2} \sum_{j=-N_x}^{N_x} H_j^{(k)} \quad H_n^{(k)} = -\frac{i}{2}(\phi_{2n+k}^\dagger \phi_{2n+k+1} - \phi_{2n+k+1}^\dagger \phi_{2n+k})$$

SIMULATING QFT

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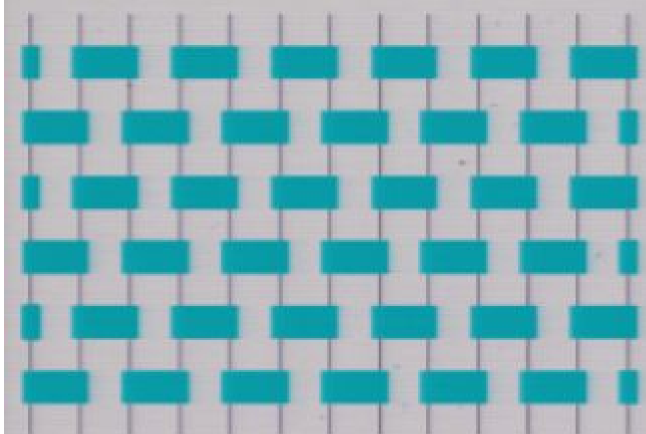

SIMULATING QFT

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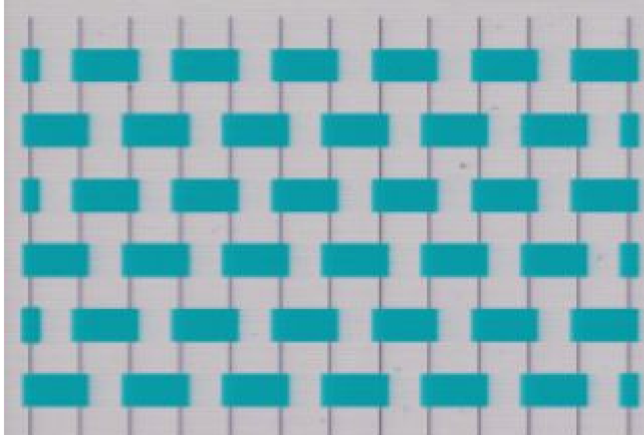

$$\left\| e^{-i\phi_t H} - \left(e^{-i\frac{\phi_t}{N}H^{(0)}} e^{-i\frac{\phi_t}{N}H^{(1)}} \right)^N \right\| \leqslant \frac{8\|H_0^{(0)}\|^2 \phi_t^2 (2N_x+1)^2}{N} \exp\left(2\phi_t (2N_x+1) \frac{N+2}{N} \|H_0^{(0)}\| \right)$$

To guarantee convergence one needs a fixed!

SIMULATING QFT

Simple scalar fields in 1 space dimension

However, for a fixed one has maximal causal speed going to infinity!

$$\frac{a}{\tau} = \frac{x/2N_x}{t/2N}, \quad \lim_{N\to\infty} \frac{a}{\tau} = \infty$$

SIMULATING QFT

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$$c = \frac{x}{t} = \frac{a2N_x}{\tau 2N} \Longrightarrow N_x = N \quad \Rightarrow \quad c = \omega a = \frac{a}{\tau} \Longrightarrow \omega = \frac{1}{\tau}$$

SIMULATING QFT

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but then Suzuki bound doesn't guarantee convergence of Trotter-ization since:

$$\left\| e^{-i\phi_t H} - \left(e^{-i\frac{\phi_t}{N}H^{(0)}} e^{-i\frac{\phi_t}{N}H^{(1)}} \right)^N \right\| \leqslant \frac{8\|H_0^{(0)}\|^2 \phi_t^2 (2N_x+1)^2}{N} \exp\left(2\phi_t (2N_x+1) \frac{N+2}{N} \|H_0^{(0)}\| \right)$$

SIMULATING QFT

Simple scalar fields in 1 space dimension

Since the phase for a swapping gate is π
the time t must be discrete

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SIMULATING QFT

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SIMULATING QFT

1ST QUANTIZATION

In a first-quantized field theory the field $\phi(x)$ is a c-function of position evolving in time---the so-called *wave-function*.

SIMULATING QFT

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Question: Which kind of computation will simulate a first-quantized theory?

Answer: a classical computation! (Runge-Kutta integration)

SIMULATING QFT

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Answer: a classical computation! (Runge-Kutta integration)

$\phi(x)$ will be described by a string of classical *infbits* $|\phi\rangle\langle\phi|$

$$\rho_{\vec{\phi}} = \otimes_n |\phi_n\rangle\langle\phi_n| \qquad \langle\phi|\phi'\rangle = \delta_{\phi\phi'} \qquad \phi \in \mathbb{C}$$

A general classical processing will be described by a classical channel:

$$\mathscr{C}(\rho_{\vec{\phi}}) = \sum_{\vec{\phi}'} p(\vec{\phi}'|\vec{\phi})\rho_{\vec{\phi}'}$$

Deterministic evolution: $p(\vec{\phi}'|\vec{\phi}) = \delta(\vec{\phi}' - f(\vec{\phi}))$

Runge-Kutta

SIMULATING QFT

1ST QUANTIZATION

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Deterministic evolution: $p(\vec{\phi}'|\vec{\phi}) = \delta(\vec{\phi}' - f(\vec{\phi}))$

namely: $\mathscr{C}(\rho_{\vec{\phi}}) = \rho_{f(\vec{\phi})}$

quantum evolution = unitary kernel:

$$\phi_i(t+\tau) = \sum_j U_{ij}\phi_j(t)$$

SIMULATING QFT

1ST QUANTIZATION BY $QCFT_1$

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What is $QCFT_1$?

SIMULATING QFT

1ST QUANTIZATION BY $QCFT_1$

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SIMULATING QFT

1ST QUANTIZATION BY $QCFT_1$

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$QCFT_2$ squanders the Hilbert space when simulating QFT_1 !

It linearly combines the eigenvalues ϕ_n of the projectors $|\phi_n\rangle\langle\phi_n|$ without making superpositions of the kets $|\phi_n\rangle$ nor making entanglements between different systems

SIMULATING QFT

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$$\phi = \begin{pmatrix} \cdots \\ \phi_{n-1} \\ \phi_n \\ \phi_{n+1} \\ \cdots \end{pmatrix}$$

Interactions between *n* quantum systems become ma
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SIMULATING QFT

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SIMULATING QFT

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Interactions between n quantum systems become matrix blocks connecting n orthogonal states of a single quantum system

$\otimes \Longrightarrow \oplus$

Time evolution:

$$\phi(t) = U_t\phi(0) := \exp(-i\omega t H)\phi(0)$$

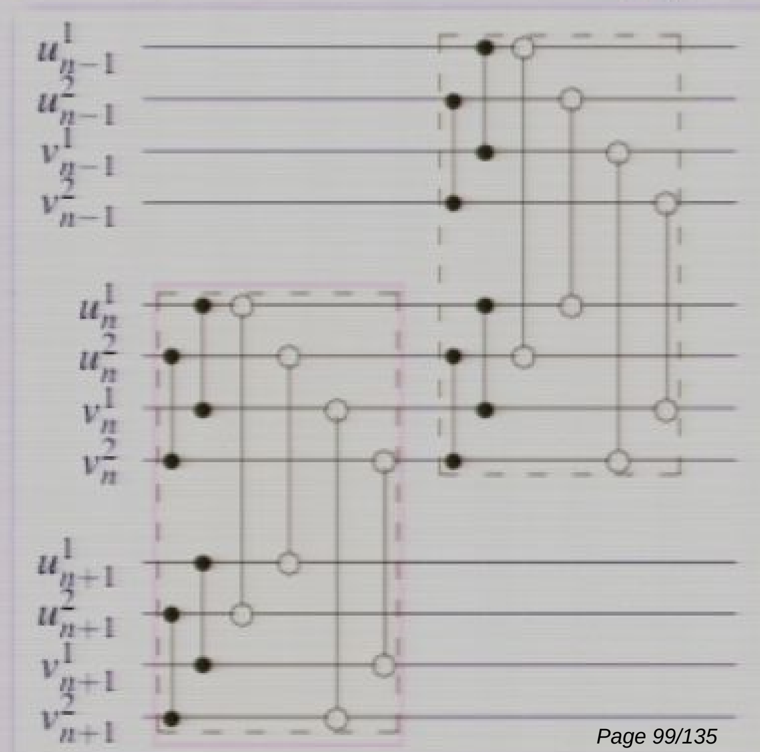
SIMULATING QFT$_1$

Dirac Particle

$$i\hbar\partial_t\psi = \begin{pmatrix} ic\hbar\sigma_x\partial_x & mc^2 \\ mc^2 & -ic\hbar\sigma_x\partial_x \end{pmatrix}\psi$$

$$\psi := \begin{pmatrix} \cdots \\ \psi_n \\ \psi_{n+1} \\ \cdots \end{pmatrix}, \qquad \psi_n = \begin{pmatrix} u_n \\ v_n \end{pmatrix} = \begin{pmatrix} u_n^1 \\ u_n^2 \\ v_n^1 \\ v_n^2 \end{pmatrix}$$

$$H = \begin{pmatrix} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & 0 & 0 & -\frac{i}{2}\sigma_x & 0 & 0 & 0 & \cdots \\ \cdots & 0 & 0 & \frac{a}{\lambda}I & \frac{i}{2}\sigma_x & 0 & 0 & \cdots \\ \cdots & \frac{i}{2}\sigma_x & \frac{a}{\lambda}I & 0 & 0 & -\frac{i}{2}\sigma_x & 0 & \cdots \\ \cdots & 0 & -\frac{i}{2}\sigma_x & 0 & 0 & \frac{a}{\lambda}I & \frac{i}{2}\sigma_x & \cdots \\ \cdots & 0 & 0 & \frac{i}{2}\sigma_x & \frac{a}{\lambda}I & 0 & 0 & \cdots \\ \cdots & 0 & 0 & 0 & -\frac{i}{2}\sigma_x & \frac{a}{\lambda}I & 0 & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \end{pmatrix}$$



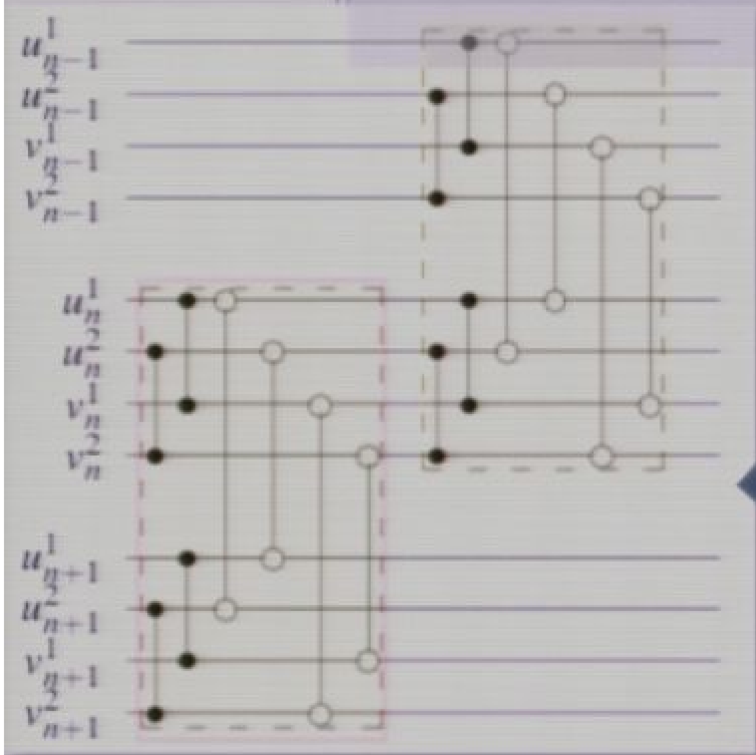
$$\lambda := \frac{\hbar}{mc} = 3.86159 * 10^{-13}$$

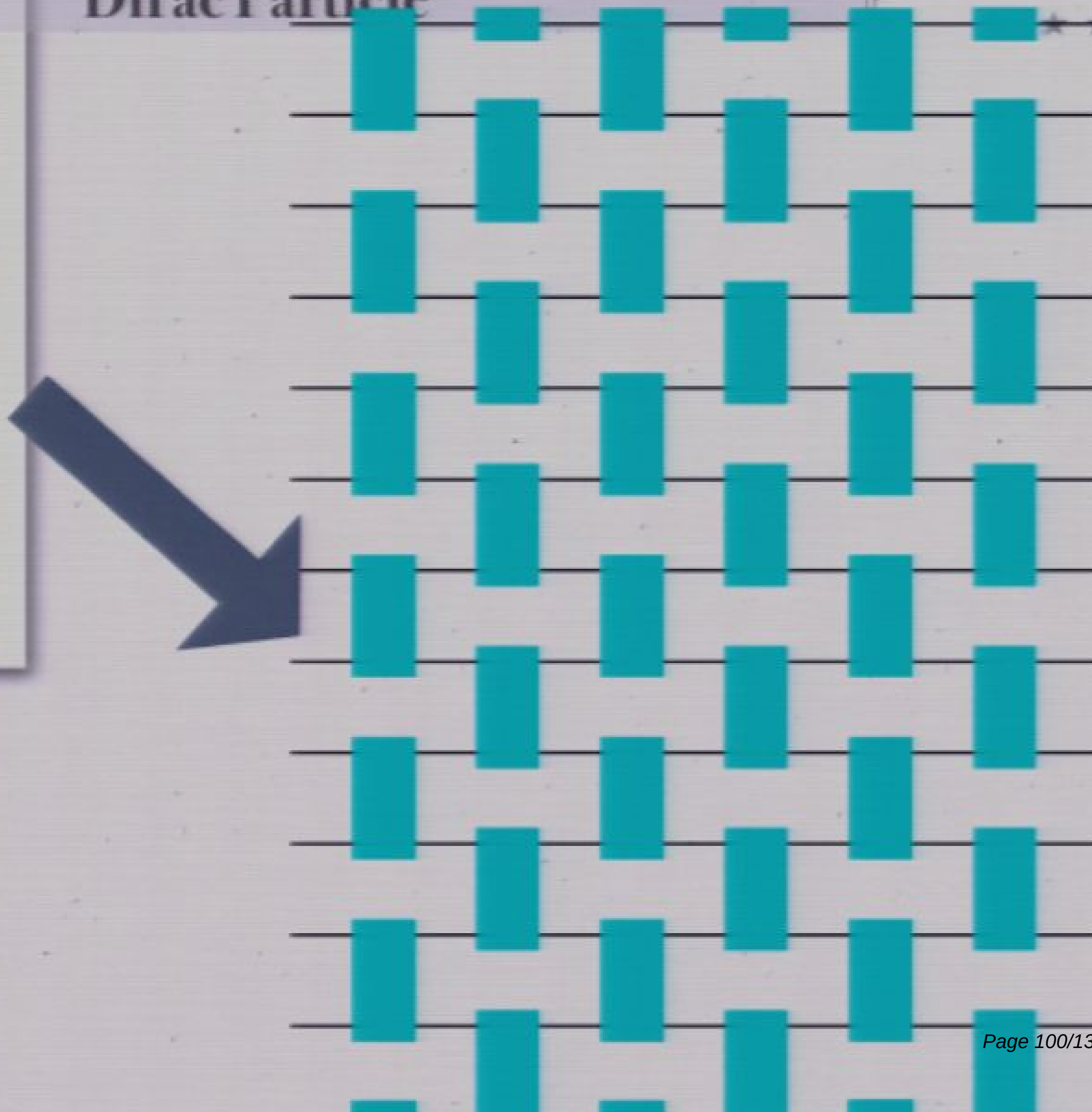
Reduced Compton wavelength

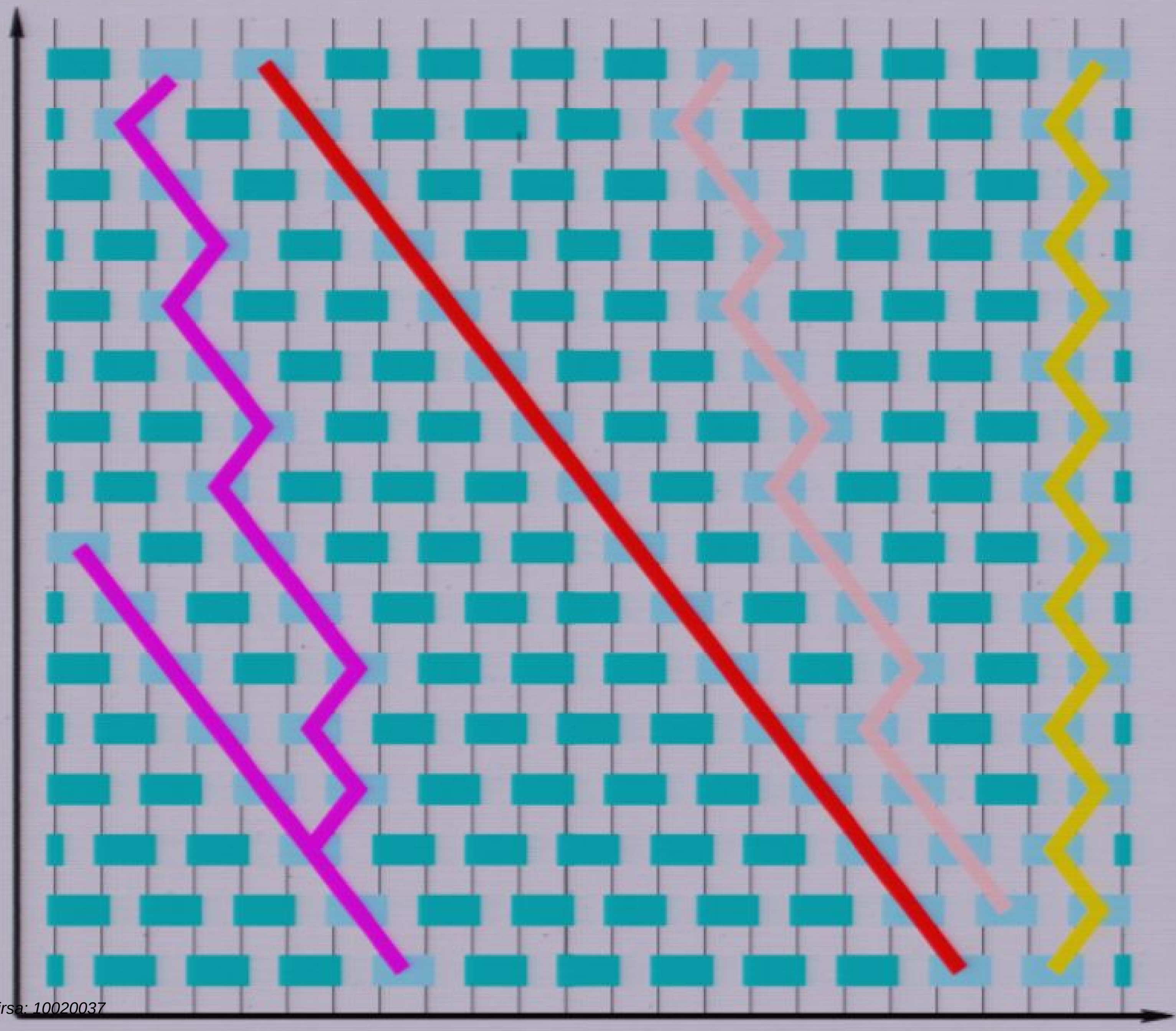
∂_x makes sense above the scale of λ

SIMULATING QFT$_1$

Dirac Particle



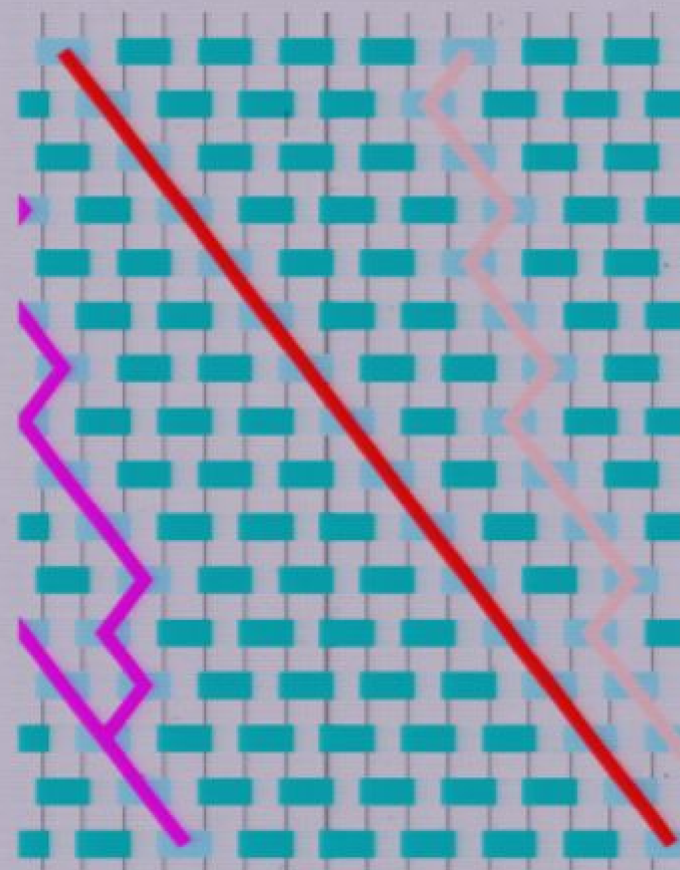




Zitterbewegung

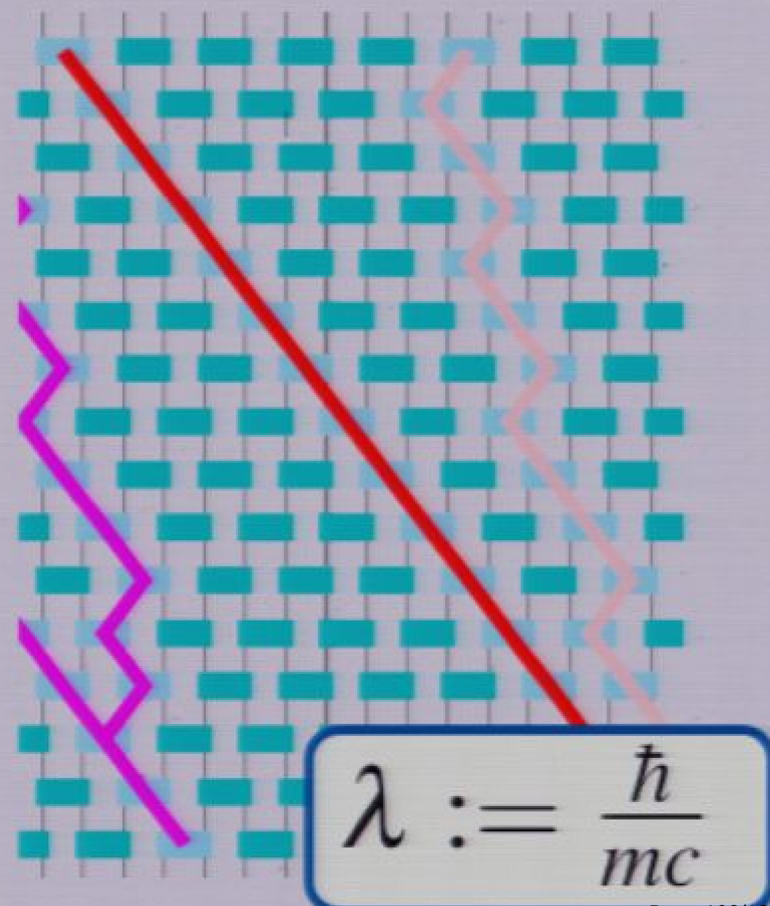
Mass:
fequency of
the zigzag

What is ħ?



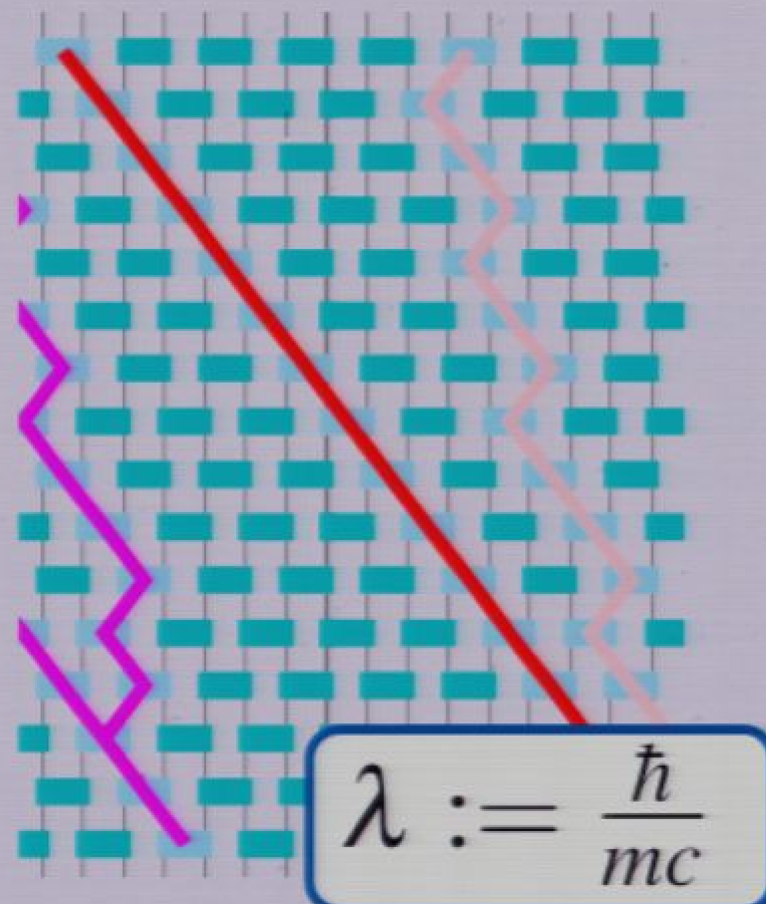
What is ħ?

- m is the ZBW frequency
- c is the max causal speed



What is ħ?

- m is the ZBW frequency
- c is the max causal speed
- ħ is the scale above which one can use ∂, i.e. at which one sees the gates!
- quantization rules "emergent" (P is a *swappiness*, X is where the qubit is ↑)



SIMULATING QFT$_1$

Schrödinger equation

$$\partial_t \phi = i\frac{\hbar}{2m}\partial_x^2 \phi$$

$$\omega = \frac{\hbar}{2ma^2}$$

$$H = \sum_j e_{j+1,j} - 2e_{j,j} + e_{j,j+1} = \begin{pmatrix} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & 2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots \\ \cdots & 1 & -2 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \\ \cdots & \cdots & \cdots & \cdots & -2 & 1 & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & 1 & -2 & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & -2 & 1 & \cdots \\ \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -2 & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \end{pmatrix}$$

$$H = H^{(0)} + H^{(1)}, \quad H^{(0)} = \sum_j H_{2j,2j+1},\; H^{(1)} = \sum_j H_{2j+1,2j+2}$$

$$H_{j,j+1} = \sum e_{j+1,j} - e_{j,j} - e_{j+1,j+1} + e_{j,j+1}$$

SIMULATING QFT$_1$

Schrödinger equation

"**Trotterize**" the Hamiltonian

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SIMULATING QFT₁

Schrödinger equation

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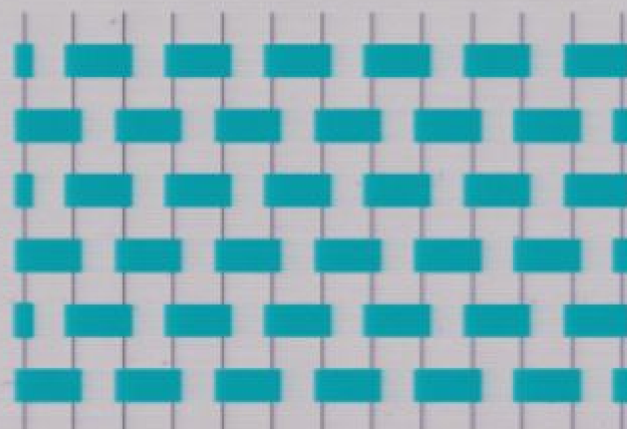
By taking the maximal causal speed equal to c namely $a \propto N^{-1}$ one obtains:

$$\omega = \frac{\hbar}{2ma^2} \propto N^2$$



a contradiction!

SIMULATING QFT_2

Dirac Field Theory

SIMULATING QFT$_2$

Dirac Field Theory

Clifford algebra $\Gamma_k := \left(\prod_{j=-\infty}^{k-1} \sigma_j^z \right) \sigma_k^-$

$$\{\Gamma_k, \Gamma_h\} = \delta_{kh}$$

Fermi scalar field: $\psi_n = \Gamma_{4n+\alpha}$

$$\{\psi(x), \psi^\dagger(x)\} = \delta(x-y)$$

$$\{\psi(x), \psi(y)\} = 0$$

$$-\frac{i}{2}(\sigma_l^+ \sigma_{l+1}^- - \sigma_l^- \sigma_{l+1}^+)$$

$$\mathscr{H} = -i\hbar c \psi^\dagger(x) \partial_x \psi(x)$$

SIMULATING QFT$_2$

Dirac Field Theory

★ ★ ★ ★ ★ ★ ★ ★

Clifford algebra $\Gamma_k := \left(\prod_{j=-\infty}^{k-1} \sigma_j^z \right) \sigma_k^-$

$$\{\Gamma_k, \Gamma_h\} = \delta_{kh}$$

Fermi scalar field: $\psi_n = \Gamma_{4n+\alpha}$

$$\{\psi(x), \psi^\dagger(x)\} = \delta(x-y)$$

$$\{\psi(x), \psi(y)\} = 0$$

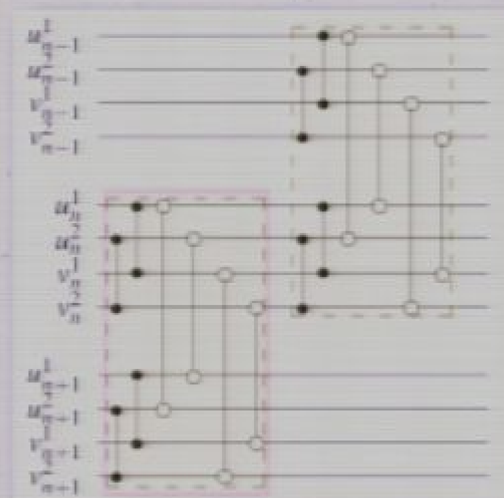
$$-\frac{i}{2}(\sigma_l^+ \sigma_{l+1}^- - \sigma_l^- \sigma_{l+1}^+)$$

$$\mathcal{H} = -i\hbar c \psi^\dagger(x) \partial_x \psi(x)$$

Dirac field:

$$\{\psi_\alpha(x), \psi_\beta^\dagger(y)\} = \delta_{\alpha\beta}\delta(x-y)$$

$$\{\psi_\alpha(x), \psi_\beta(y)\} = 0$$



$$\psi(n) = \begin{pmatrix} u_1(n) \\ u_2(n) \\ v_1(n) \\ v_2(n) \end{pmatrix}$$

$$H = \begin{pmatrix} \frac{i}{2}\sigma_x(\delta_+ - \delta_-) & \frac{a}{\lambda} I \\ \frac{a}{\lambda} I & -\frac{i}{2}\sigma_x(\delta_+ - \delta_-) \end{pmatrix}$$

SIMULATING QFT_2

Dirac Field Theory

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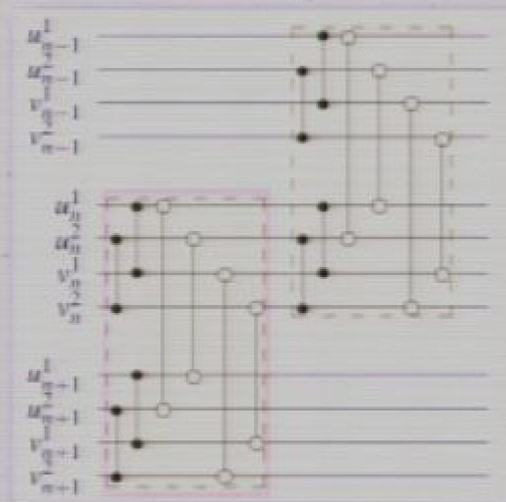


$$\psi(n) = \begin{pmatrix} u_1(n) \\ u_2(n) \\ v_1(n) \\ v_2(n) \end{pmatrix}$$

$$\psi_\alpha(n) \overset{?}{=} \Gamma_{4n+\alpha}$$

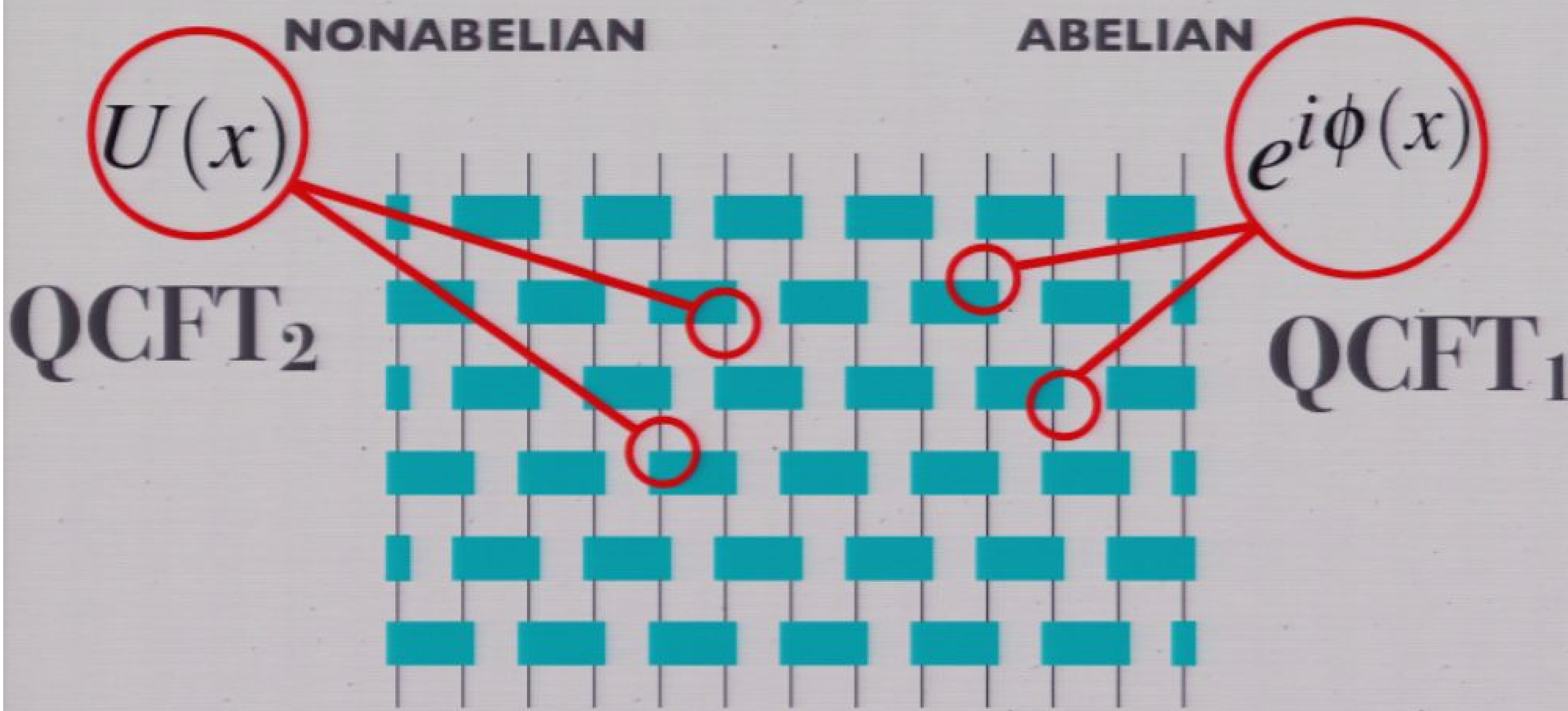
$$H = \begin{pmatrix} \frac{i}{2}\sigma_x(\delta_+ - \delta_-) & \frac{a}{\lambda}I \\ \frac{a}{\lambda}I & -\frac{i}{2}\sigma_x(\delta_+ - \delta_-) \end{pmatrix}$$

$$\sigma_l^+\sigma_{l+1}^z\ldots\sigma_{l+k-1}^z\sigma_{l+k}^- + \text{h. c.} \;?$$

QFT cure: Grassmann variables!!

SIMULATING QFT

GAUGE INVARIANCE

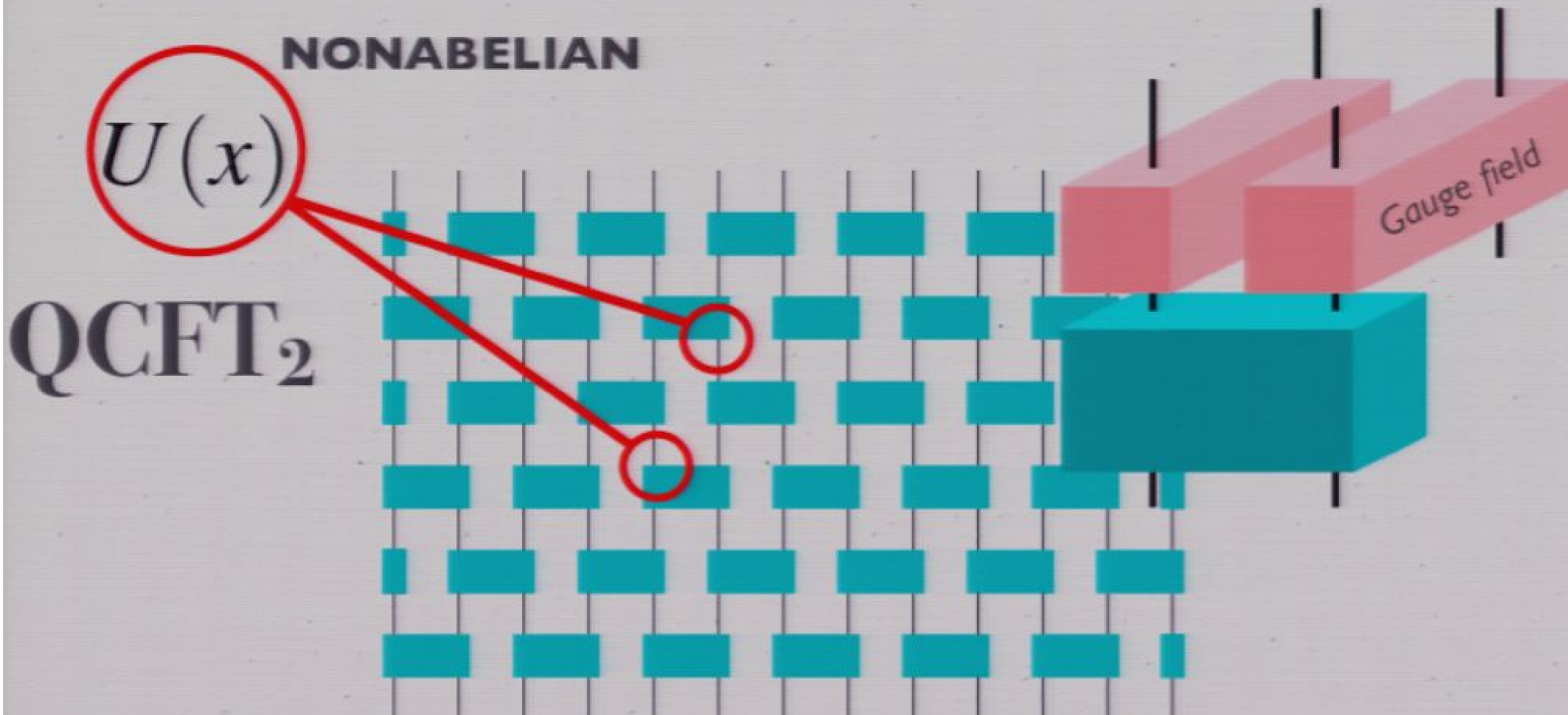


SIMULATING QFT

GAUGE INVARIANCE

★ ★ ★ ★ ★ ★ ★ ★

NONABELIAN

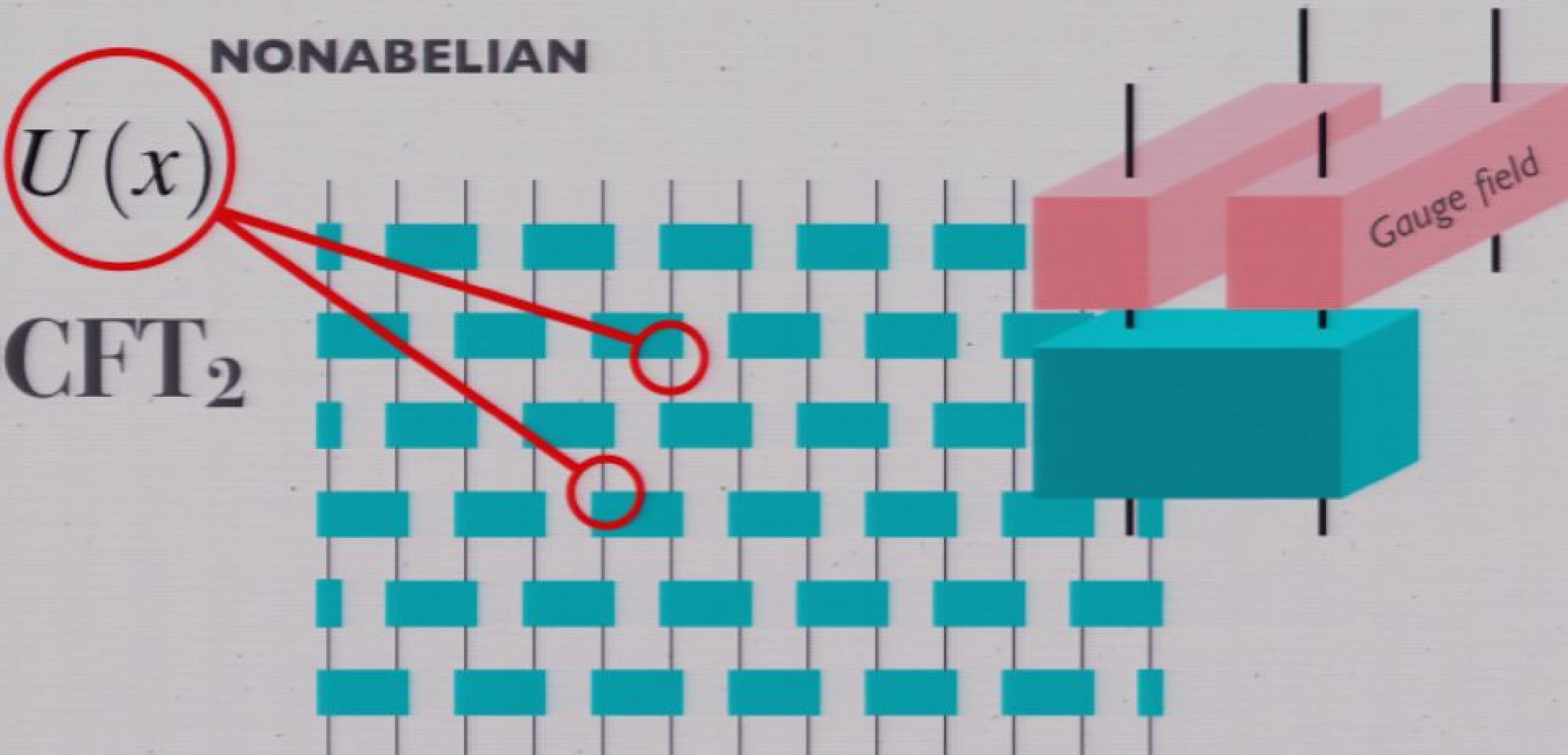


SIMULATING QFT

GAUGE INVARIANCE

NONABELIAN

$QCFT_2$



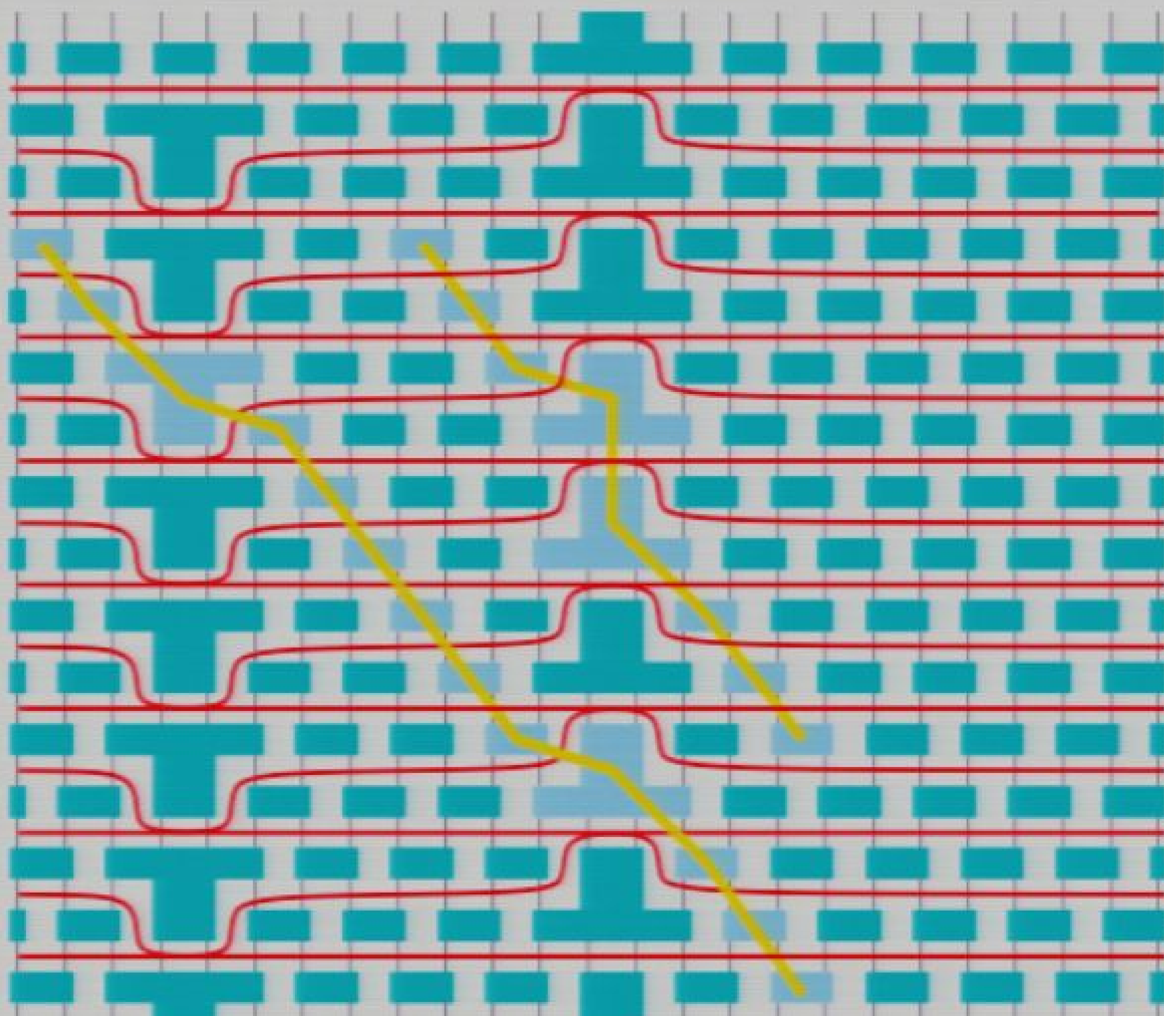
Natively nonabelian Gauge theory!
and on ... foliation !!!

Good for Gravity!

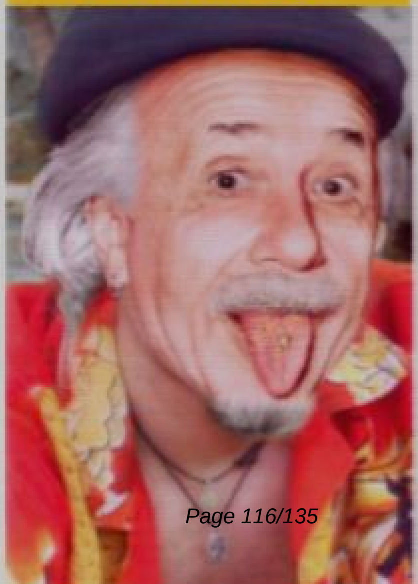
PLAY GOD WITH QCFT

or else: Einstein demystified

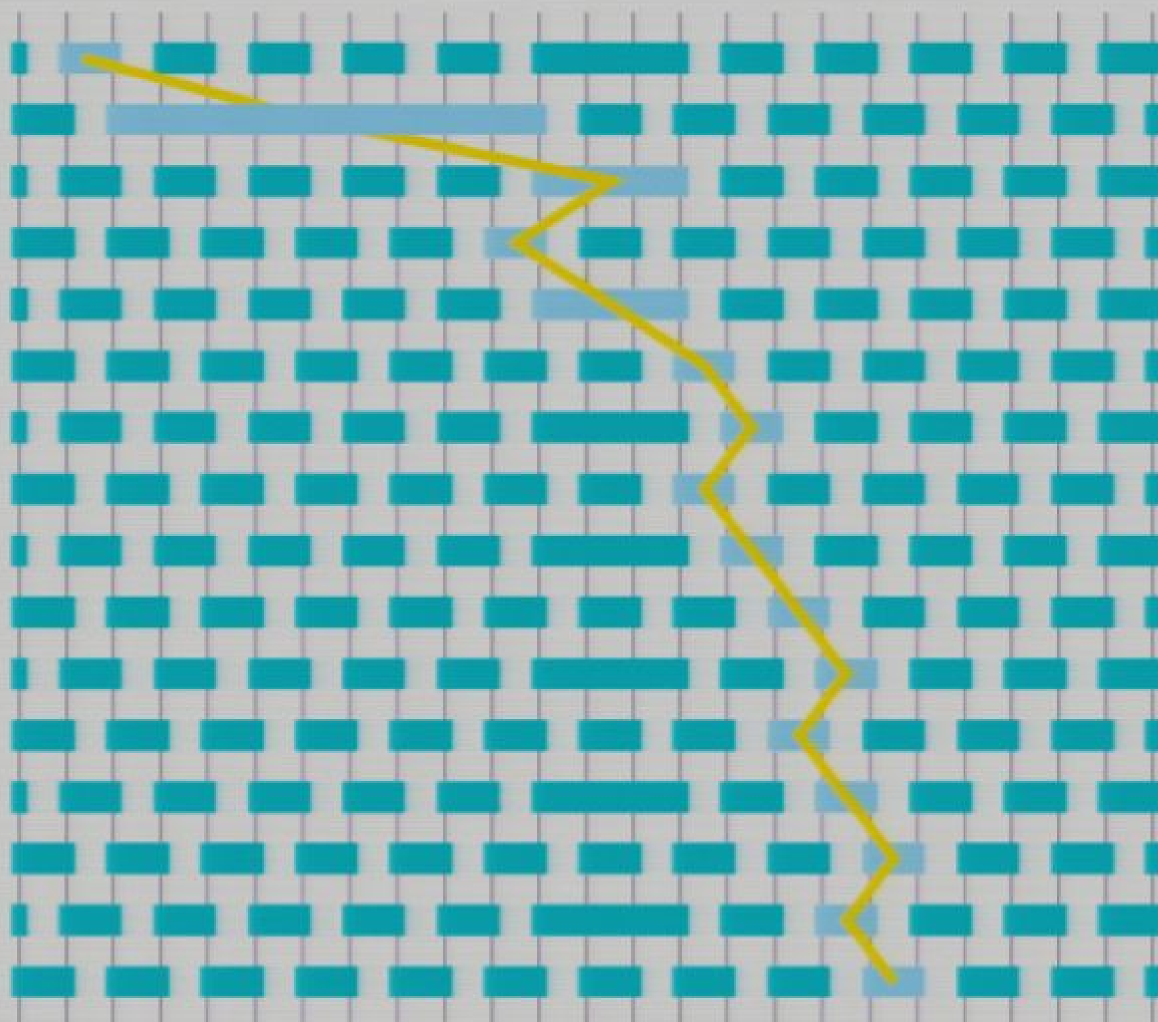
GR from QT?



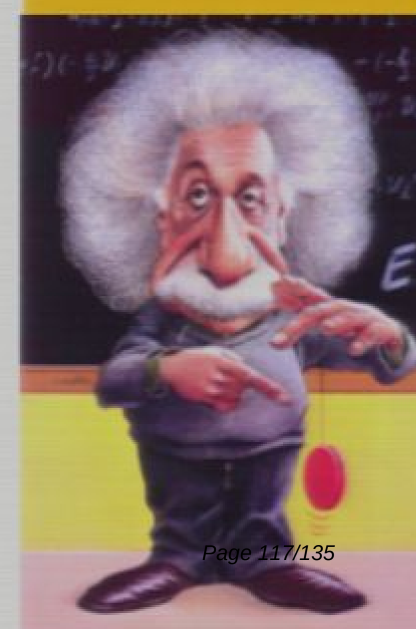
positive
and
negative
masses



GR from QT?

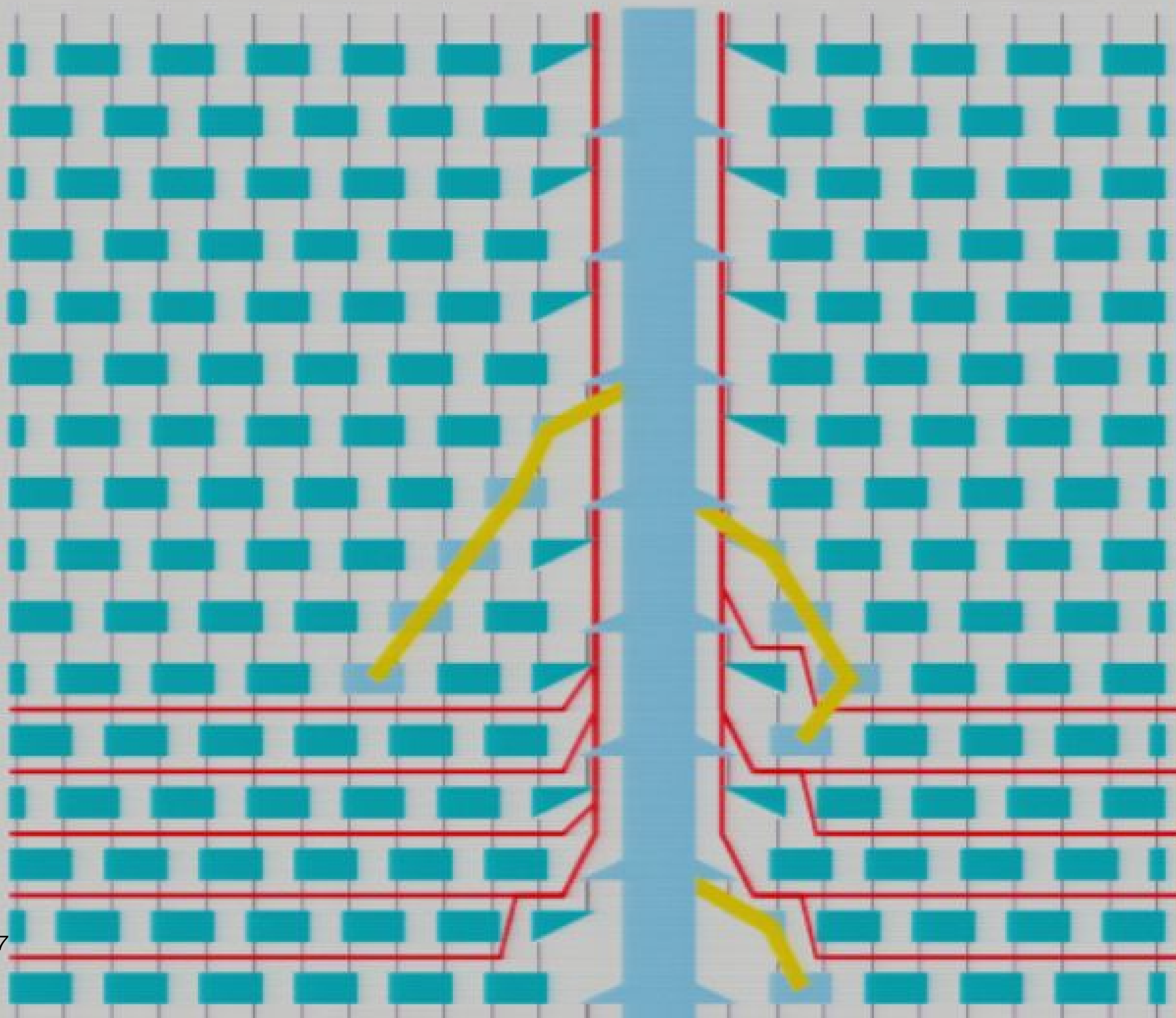


a worm hole!

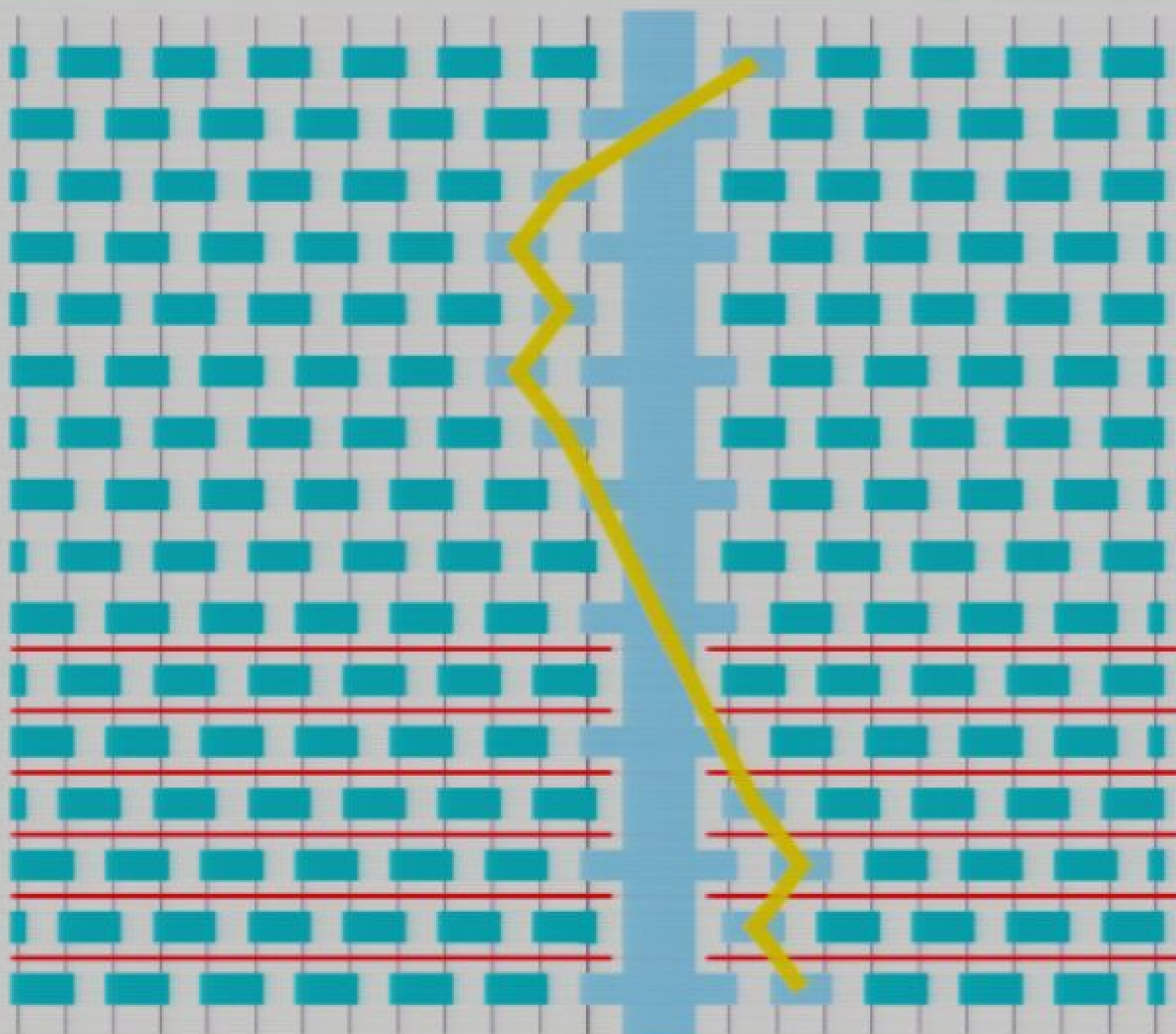


GR from QT?

a black hole!

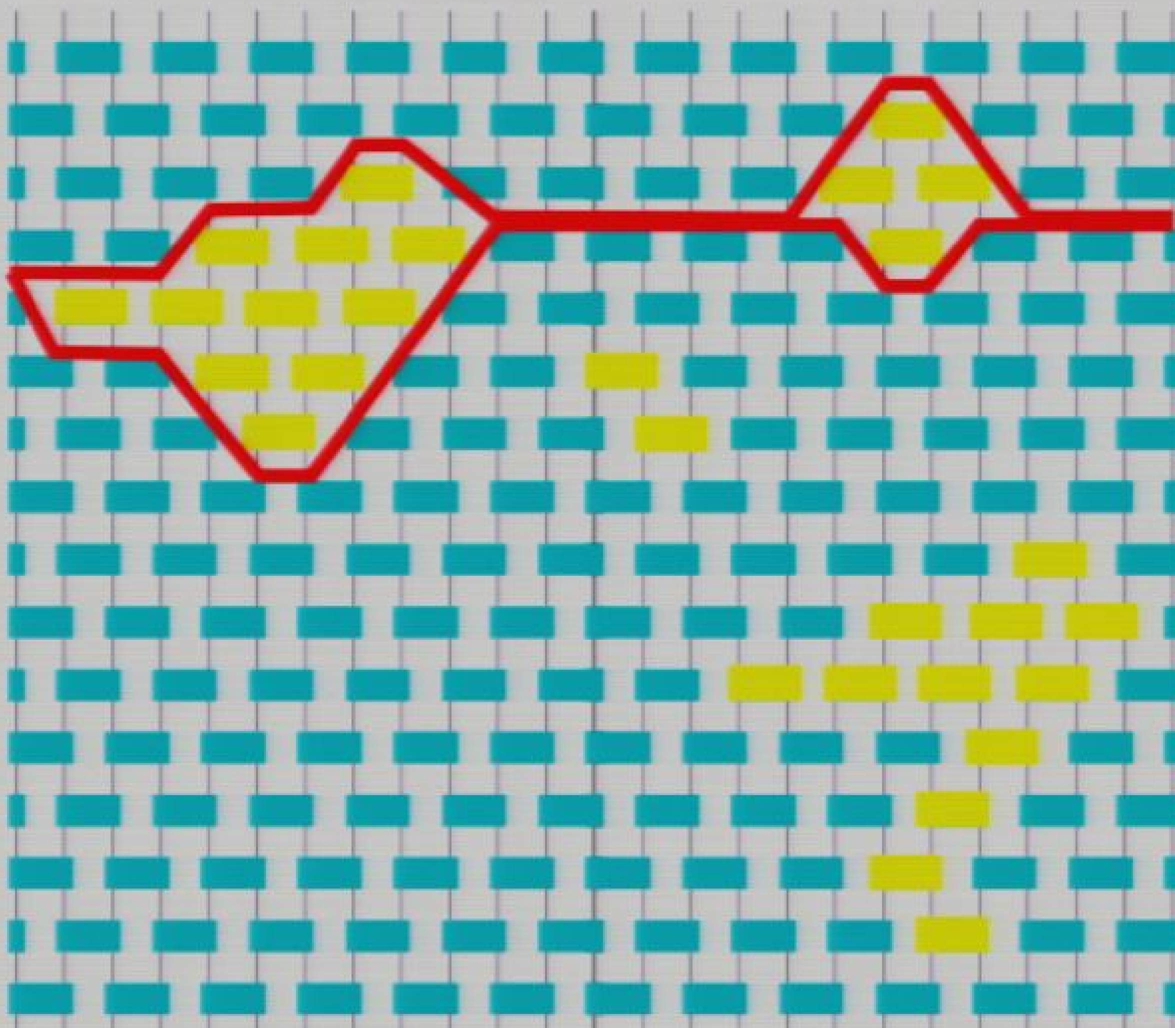


GR from QT?



a time tunnel!

GR from QT?



patterns?

Einstein operationalist?

Einstein's disagreement with the operationalist approach was criticized by Bridgman‡ as follows: *"Einstein did not carry over into his general relativity theory the lessons and insights he himself has taught us in his special theory."*

Bridgman, Einstein's Theories and the Operational Point of View, in: P.A. Schilpp, ed., Albert Einstein: Philosopher-Scientist, Open Court, La Salle, Ill., CUP, 1982, Vol. 2, p. 335-354.

Advantages of QCFT versus QFT

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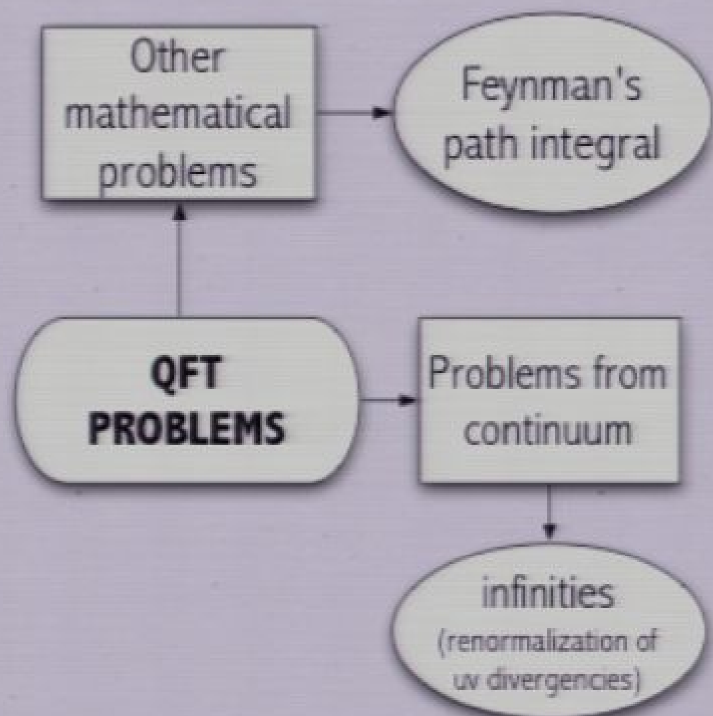
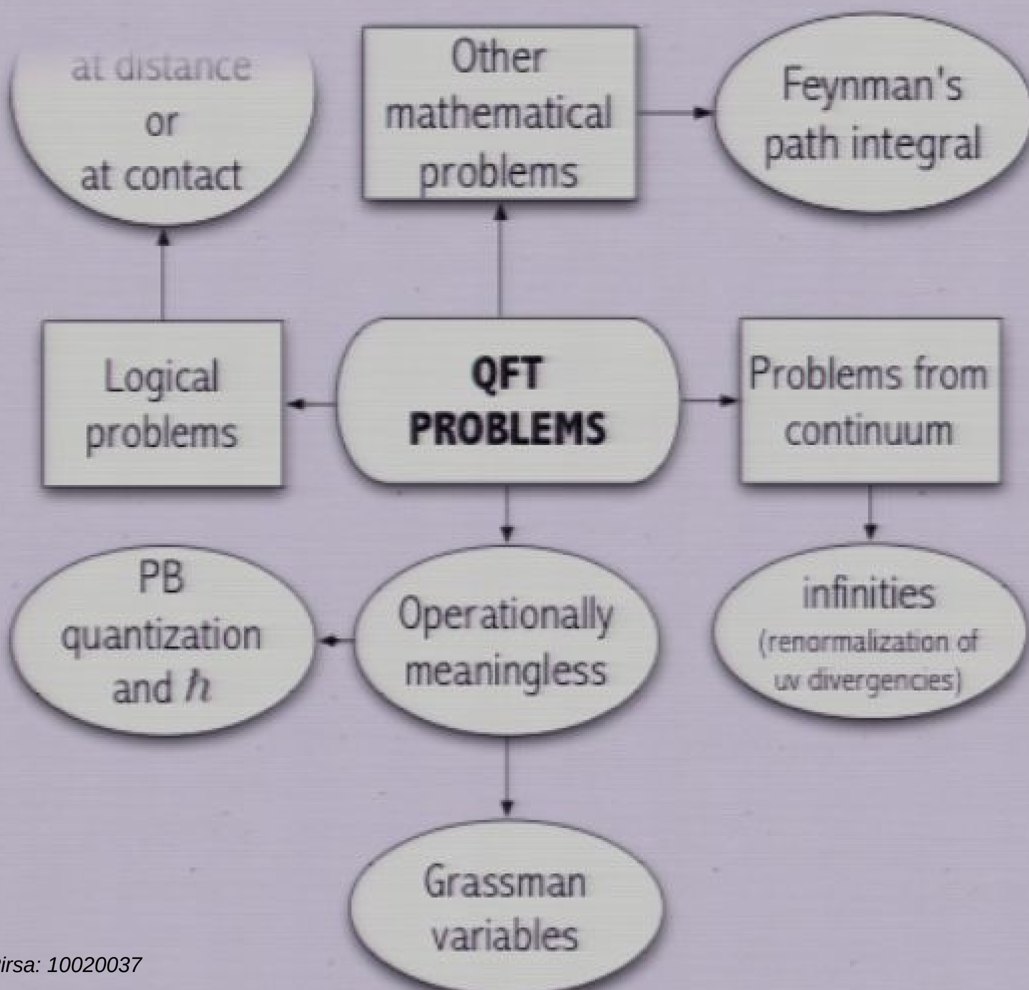
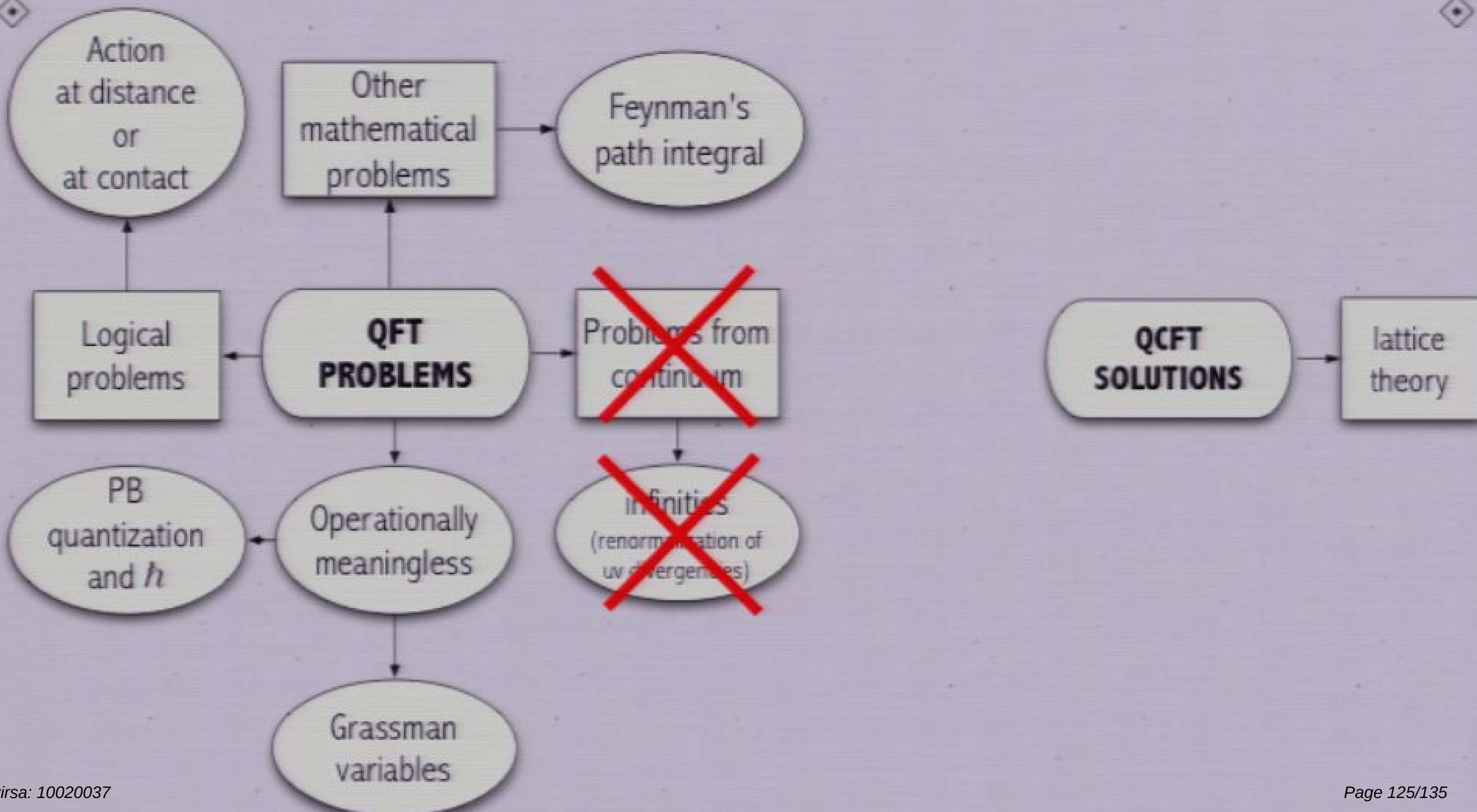


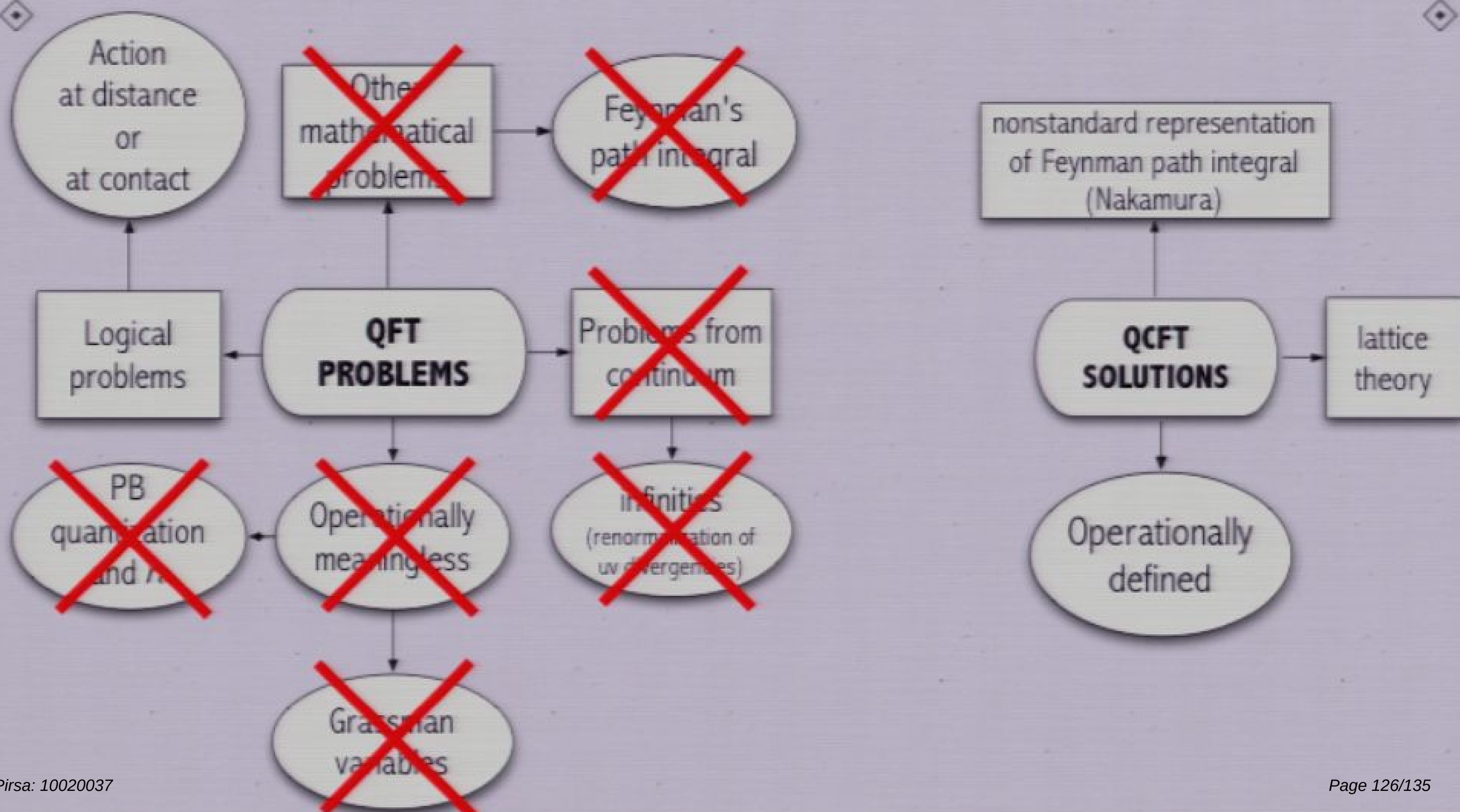
Advantages of QCFT versus QFT



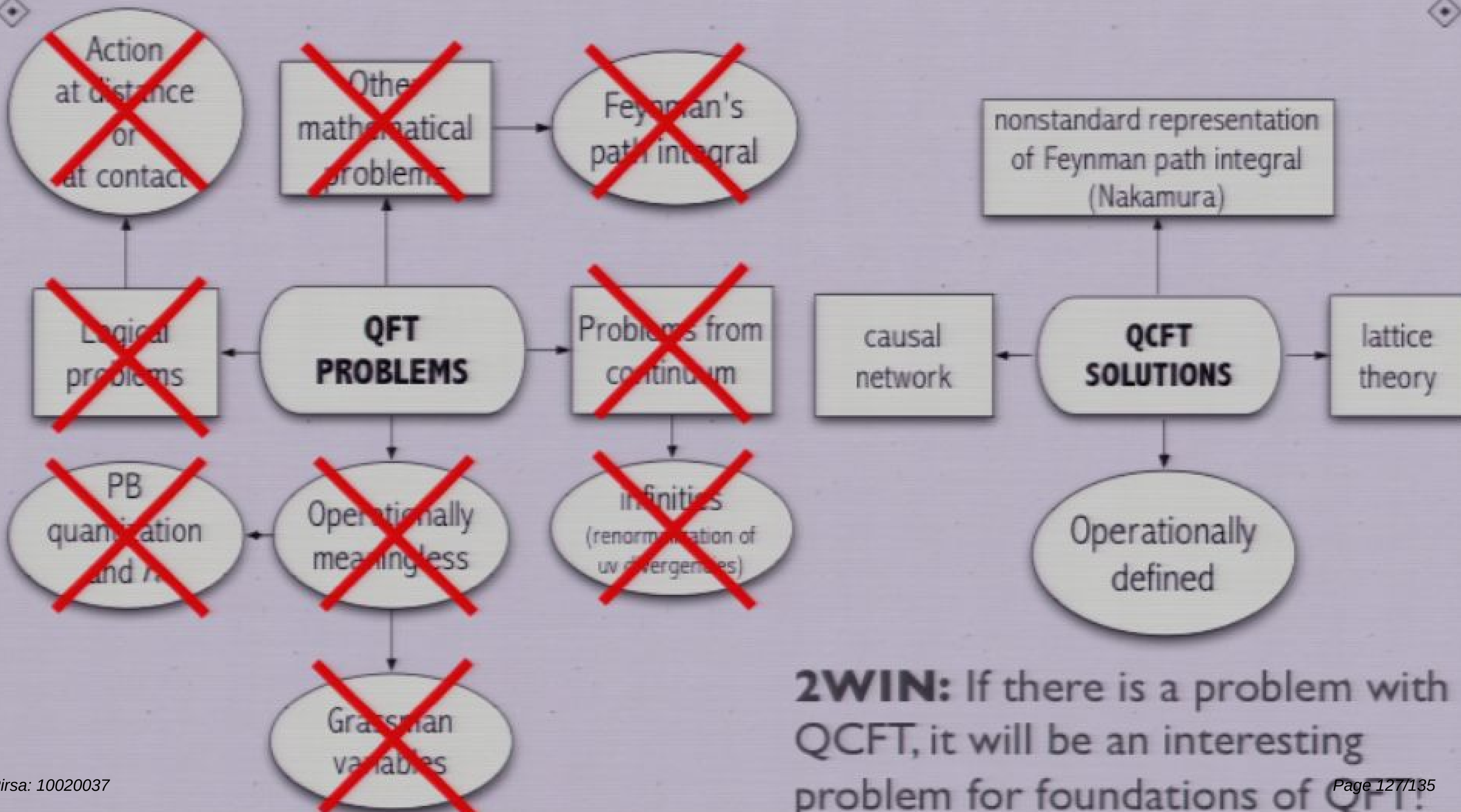
Advantages of QCFT versus QFT



Advantages of QCFT versus QFT



Advantages of QCFT versus QFT



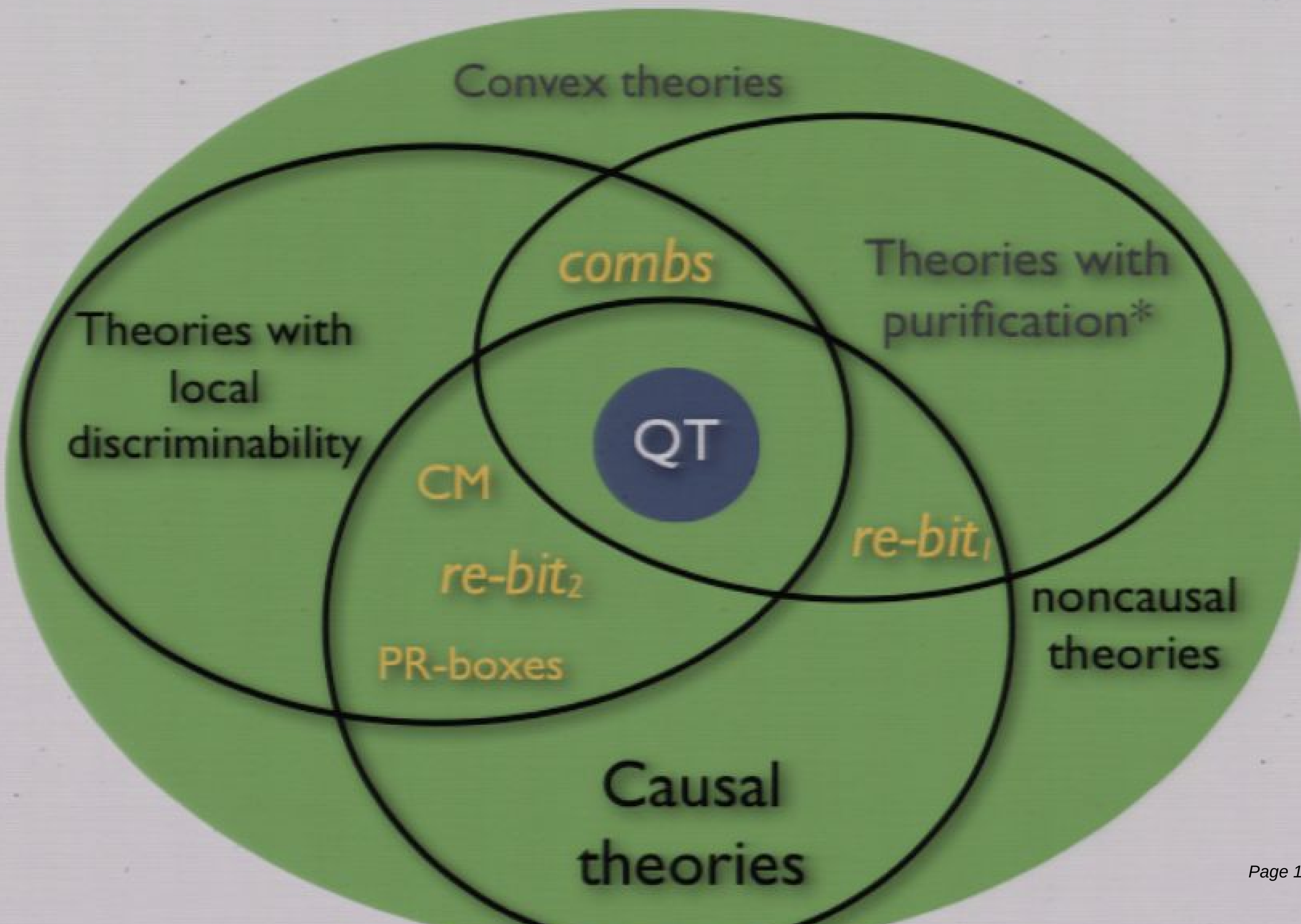
2WIN: If there is a problem with QCFT, it will be an interesting problem for foundations of QFT!

Moreover, you can change the computational engine from QT to super-QT, or even non-causal OpT, without changing the theoretical framework

THE PRINCIPLE OF THE QUANTUMNESS

Nature loves to trick us?

Operational theories



“Emergent” Physics

* Relativity
* Gravity
* Field Theory
* Quantization rules and ħ
* …

TODO list

* Improve Suzuki bound
* Derive Lorentz covariance of field
* Rederive quantization rules
* Microcausality:
  * Fermi (Grassman var.)
  * Bose
  * para-statistics?
* Derive a 1dim toy nonabelian gauge theory
* Derive Feynman path integral via Trotter
* Connect Lagrangian density with a circuit tile
* Explore connections with lattice theories
* Rederive GR Einstein's equation
* Explore Penrose spin-networks, Regge calculus, etc.
* Rederive gauge theories
* Write a new Theory of ... Quantum Gravity!!!

Concluding remarks

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* QCFT seems to have many advantages versus QFT
* It puts the finger on the foundational problems in QFT
* It is QG-ready
* It offers a first test of Lucien Hardy approach to QG
* It's fun

TODO list

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No Signal
VGA-1