PHYSICS AS INFORMATION THEORY

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OUTLINE

- Informational axiomatization of Quantum Theory
- How space-time and relativistic covariance emerge from the quantum computation
- What is the information-theoretical meaning of inertial mass and $\hbar$, and how the quantum field emerges
- Observational consequences: mass-dependent refraction index of vacuum

OPERATIONAL FRAMEWORK

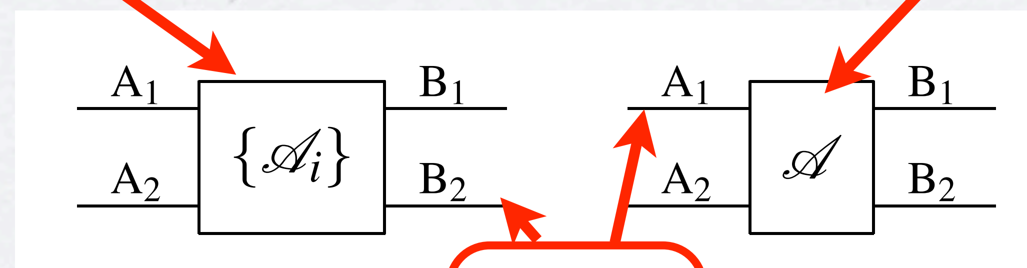
Notions: coarse-graining, refinement, refinement set, atomic/indivisible

Probabilistic operational theory: every closed circuit made of events is associated to a probability.

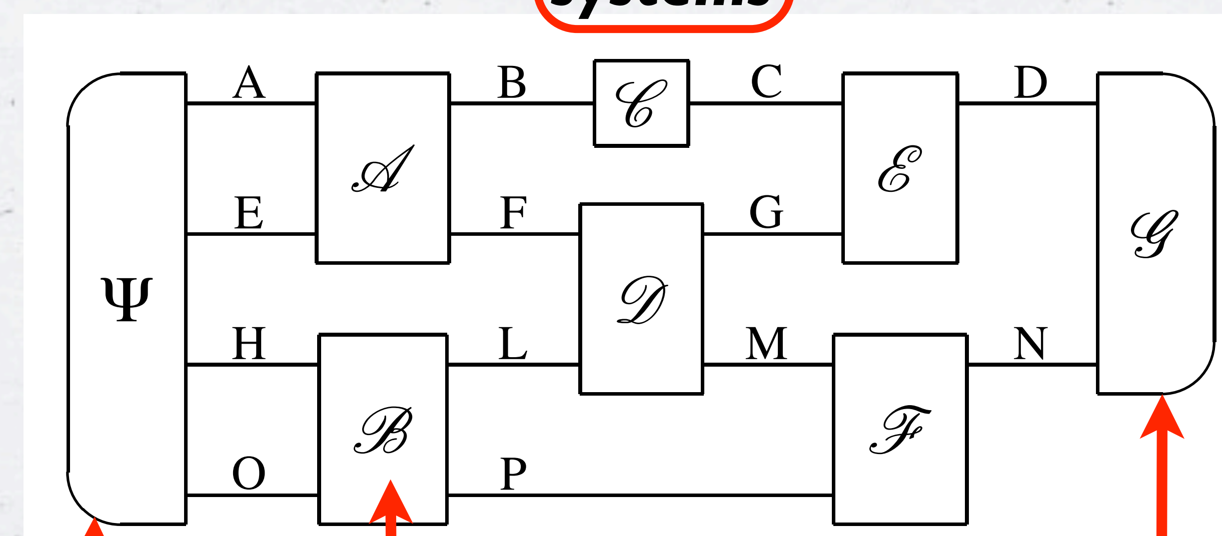
D'Ariano in *Philosophy of Quantum Information and Entanglement,* A. Bokulich and G. Jaeger (Cambridge Un. Press 2010)

Chiribella, D'Ariano, and Perinotti, PRA **81** 062348 (2010)

test **event**



systems



Transformation (equivalence class of events)

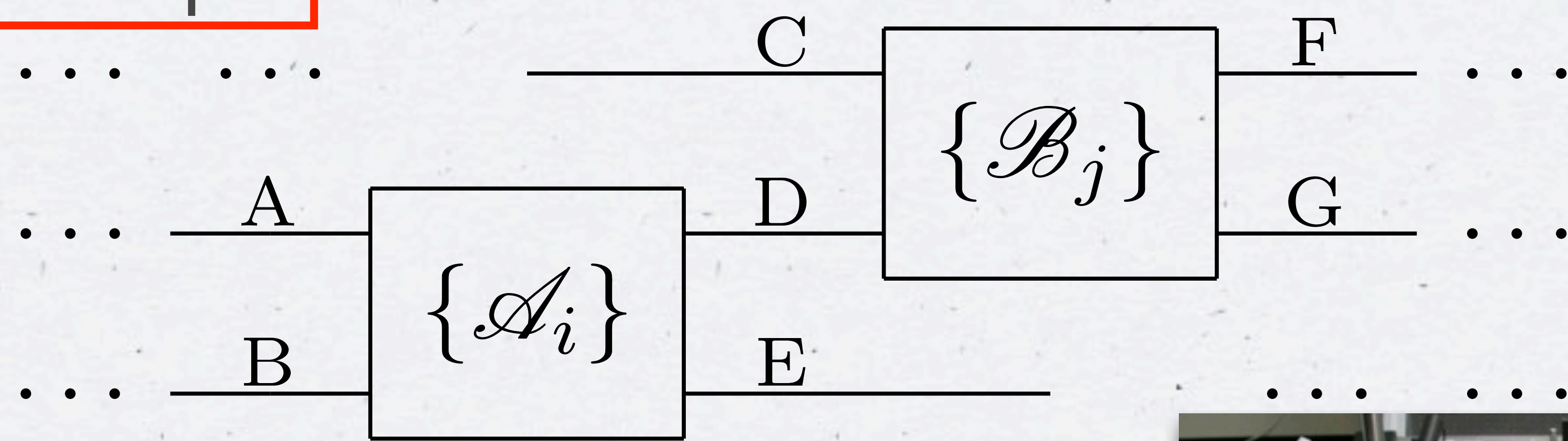
State (equivalence classes of ...) ***Effect***

no loops (DAG)

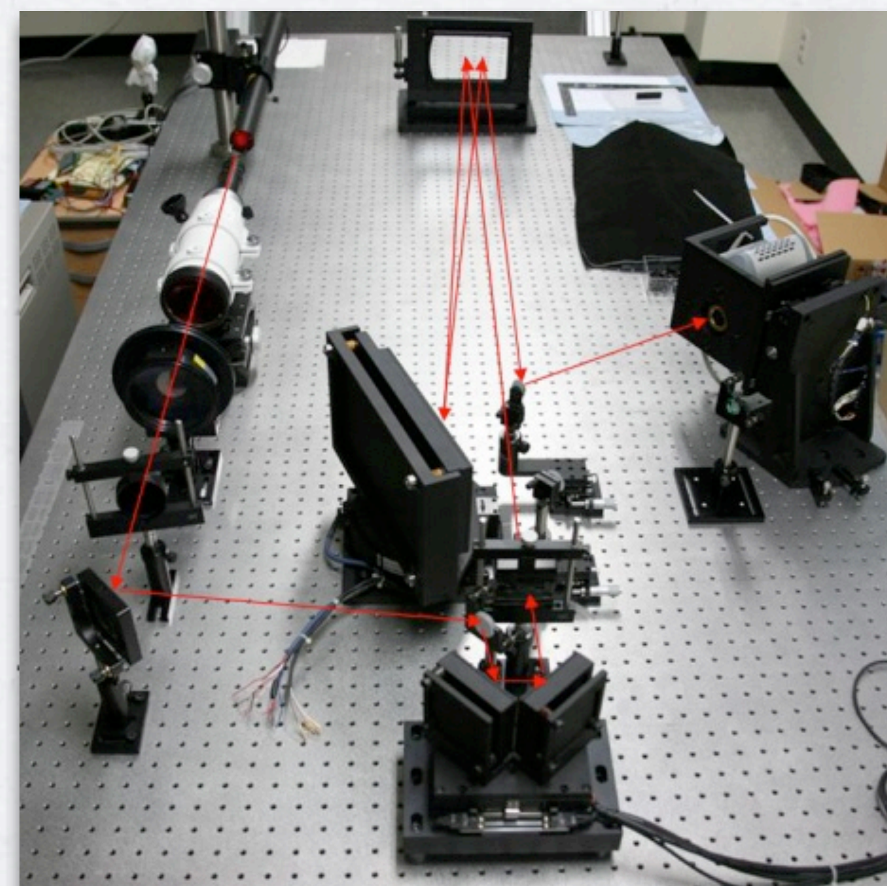
CAUSAL PROBABILISTIC THEORIES

Input → Output

DAG



A theory is *causal* if for any two tests that are input-output connected the marginal probability of the input event is independent on the choice of the output test.

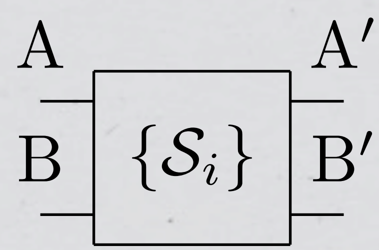


G. M. D'Ariano in *Philosophy of Quantum Information and Entanglement*, A. Bokulich and G. Jaeger (CUP, Cambridge UK, 2010).

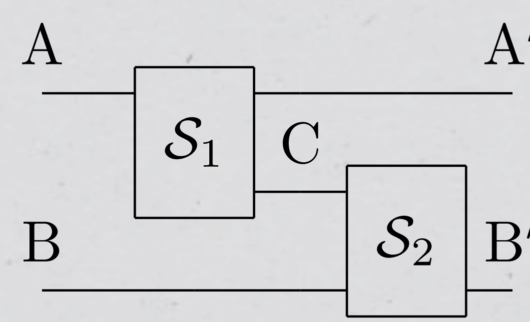
SKIP

TRANSLATION IN TERMS OF INFORMATION PROCESSING

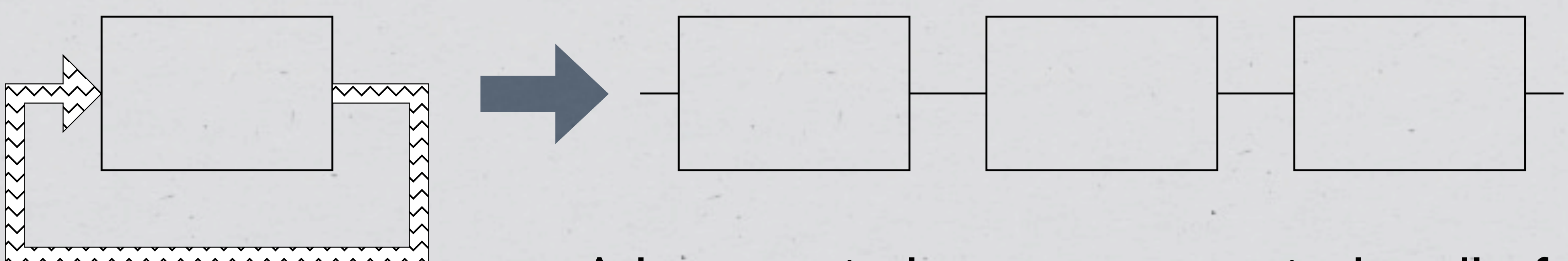
- *Test/Event* → ***subroutine***
- *Transformation* → **information processing**
- *System* → ***register***
- *States* → ***initialization***
- *Effects* → ***readout***
- ... *Pure state* → ***indivisible initialization,*** *etc..*



(subroutines are generally *refinable*)

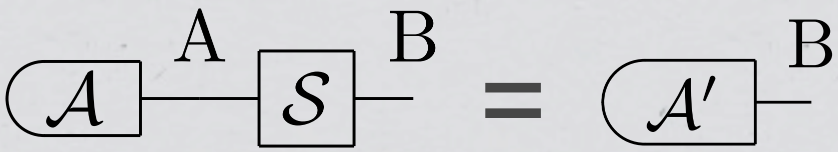


We can **compose processings** connecting input with outputs of the same type



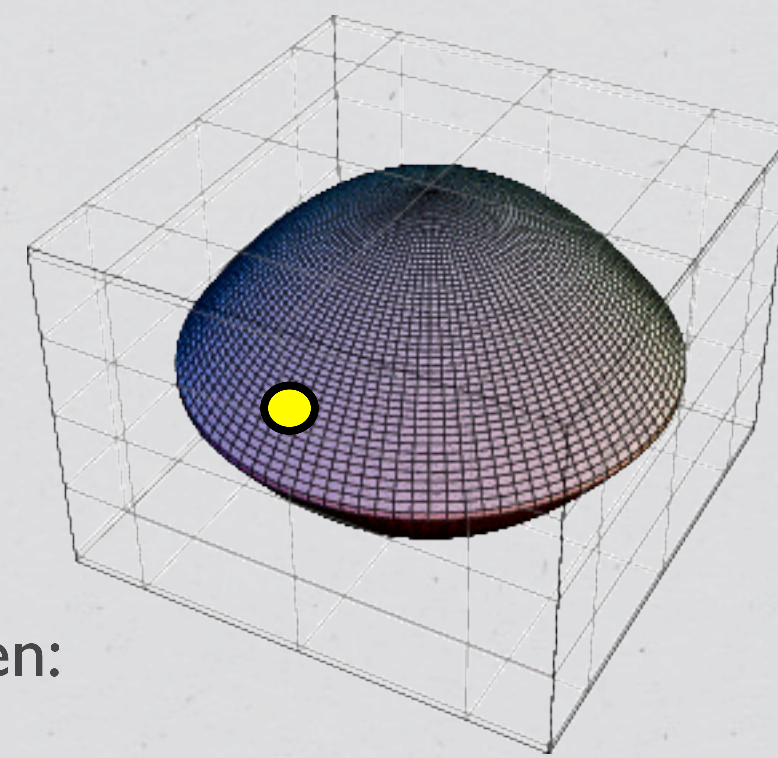
- A box precisely represents a <u>single call</u> of the processing
- The circuit represents the <u>entire run, not a flow diagram</u>

TRANSLATION IN TERMS OF INFORMATION PROCESSING



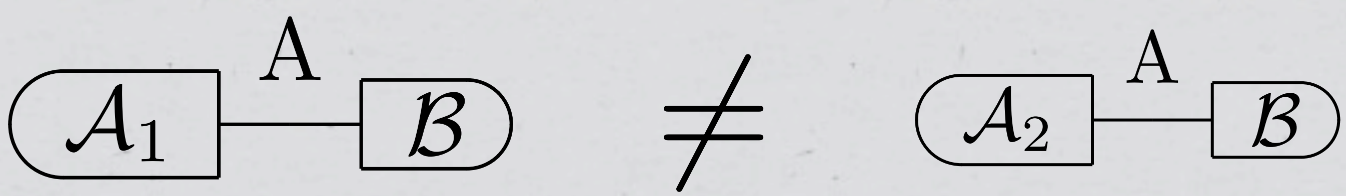
Initialization followed by a processing = new initialization

The **domain** of a processing is the set of its possible initializations, its **range** the set of its possible readouts.



An initialization is **specific** when its refinement set is not the whole set of initializations.

Two initializations $\mathcal{A}_1$ and $\mathcal{A}_2$ are **discriminable** when:



and the discrimination is **perfect** when the two probabilities are 0 and 1

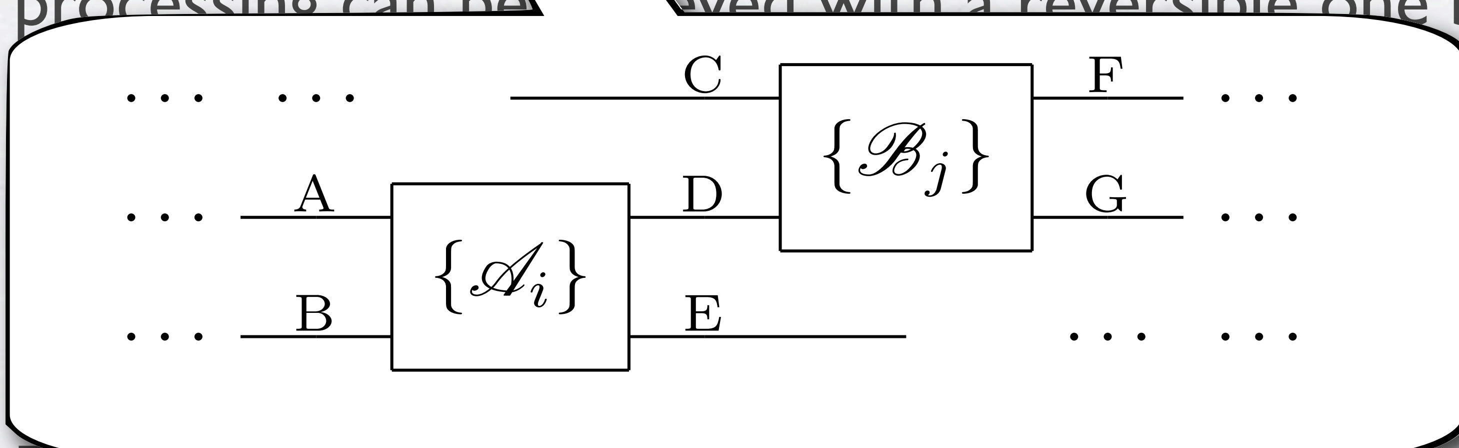
THE PRINCIPLE OF THE QUANTUMNESS

POSTULATES FOR QT

P1. ***Causality:*** The occurrence of a component processing cannot depend on the cho e of the processing at its output (i. e. information flows only from input to output).

P2. ***Loca eadability:*** We can discriminate two initializations of multiple registers by readouts single registers.

P3. ***Reversibili nd Indivisibility of Computation:*** Every information processing can be eved with a reversible one by adding a register in an indivisible



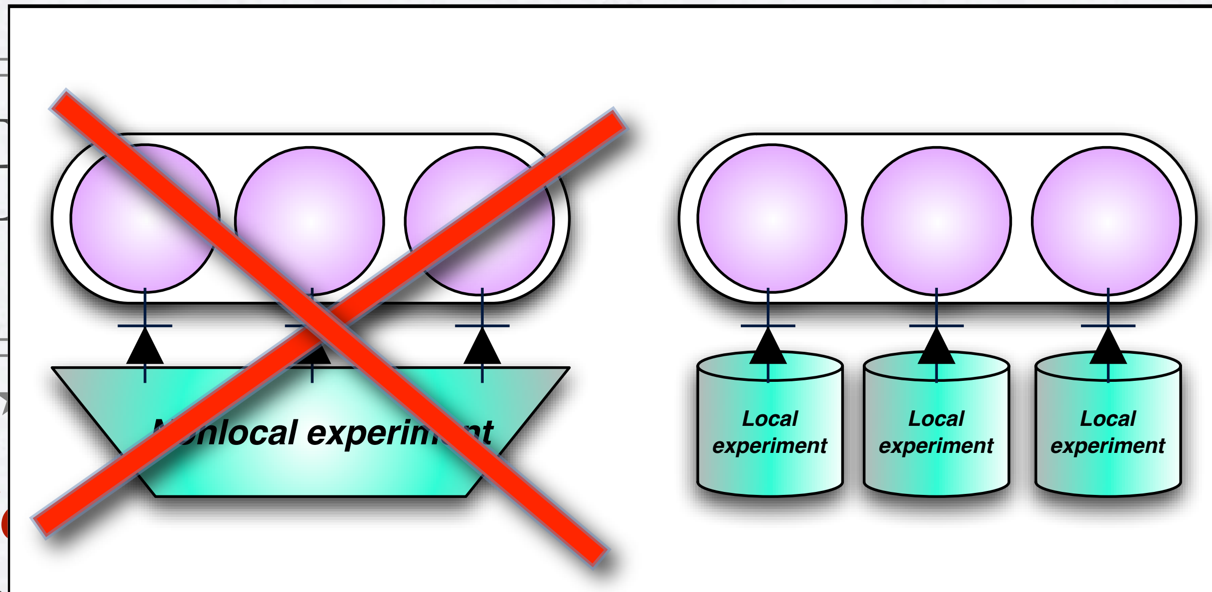
: The processing corresponding to essings is itself indivisible.

P5. ***Discriminability of Specific Initializations:*** For any specific initialization there exists another initialization that can be perfectly discriminated from it.

P6. ***Lossless Compressibility:*** For any initialization there exists an encoding which is perfectly decodeable on its refinement set, and the encoded initialization is not specific.

TH… HE QU… SS

FOR C…



THE ORIGIN OF THE COMPLEX TENSOR PRODUCT

P1. C… t processing ca… choice… the processing at its output (i. e. information flows only from… ut to output).

P2. ***Local Readability:*** We can discriminate two initializations of multiple registers by readouts on single registers.

P3. ***Rev…sibility and Indivisibility of Computat…*** processing… be achieved with a reversible one by… initialization.

CRUCIAL IN REDUCING EXPERIMENTAL COMPLEXITY, BY GUARANTEEING THAT ONLY LOCAL (JOINTLY EXECUTED) MEASUREMENTS ARE SUFFICIENT TO RETRIEVE A COMPLETE INFORMATION OF A COMPOSITE SYSTEM, INCLUDING ALL CORRELATIONS BETWEEN THE COMPONENTS

Holism

Reductionism

P4… ***n:*** The… th… essings is its…

P5… ***ons:*** For any specific initialization th… ectly discriminated from it.

P6. … For any initialization there exists an encoding which is perfectly decodeable on its refinement set, and the encoded initialization is not specific.

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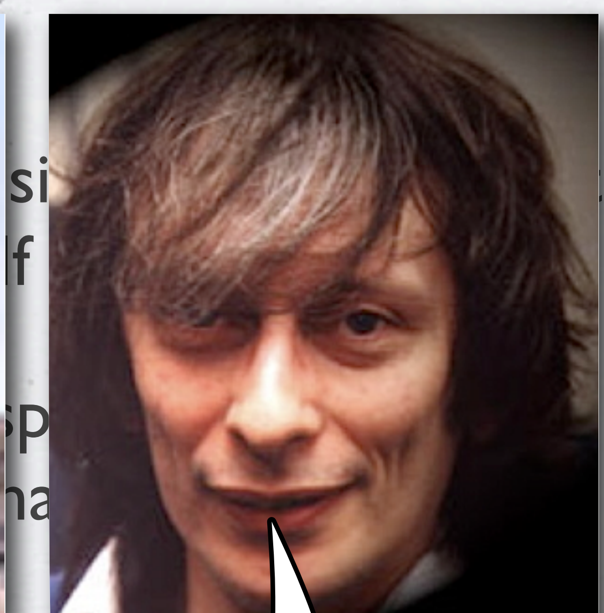
P4. ***Indiv... ility of Processing Compo...*** ...si... o th... ...f two indivisibl... ...f

P... ...***ific Initia...*** ...sp... t... ...n that can b... ...a...

P... ...: For any initia... ...e exist... ...ich is p... ...nement set, a... ...d... ...s.

THE MOST "QUANTUM" POSTULATE

- ALL POSTULATES APART FROM P3 ARE SATISFIED BY CLASSICAL THEORY, P3 IS NOT SATISFIED BY PR BOXES
- NO KNOWN THEORY (APART FROM QT) SATISFYING P1, P2, AND P3
- IT IS THE BASIS OF MOST QUANTUM INFORMATION PROTOCOLS: TELEPORTATION, ERROR CORRECTION, NO-CLONING THEOREM, ANCILLA-ASSISTED TOMOGRAPHY, ...



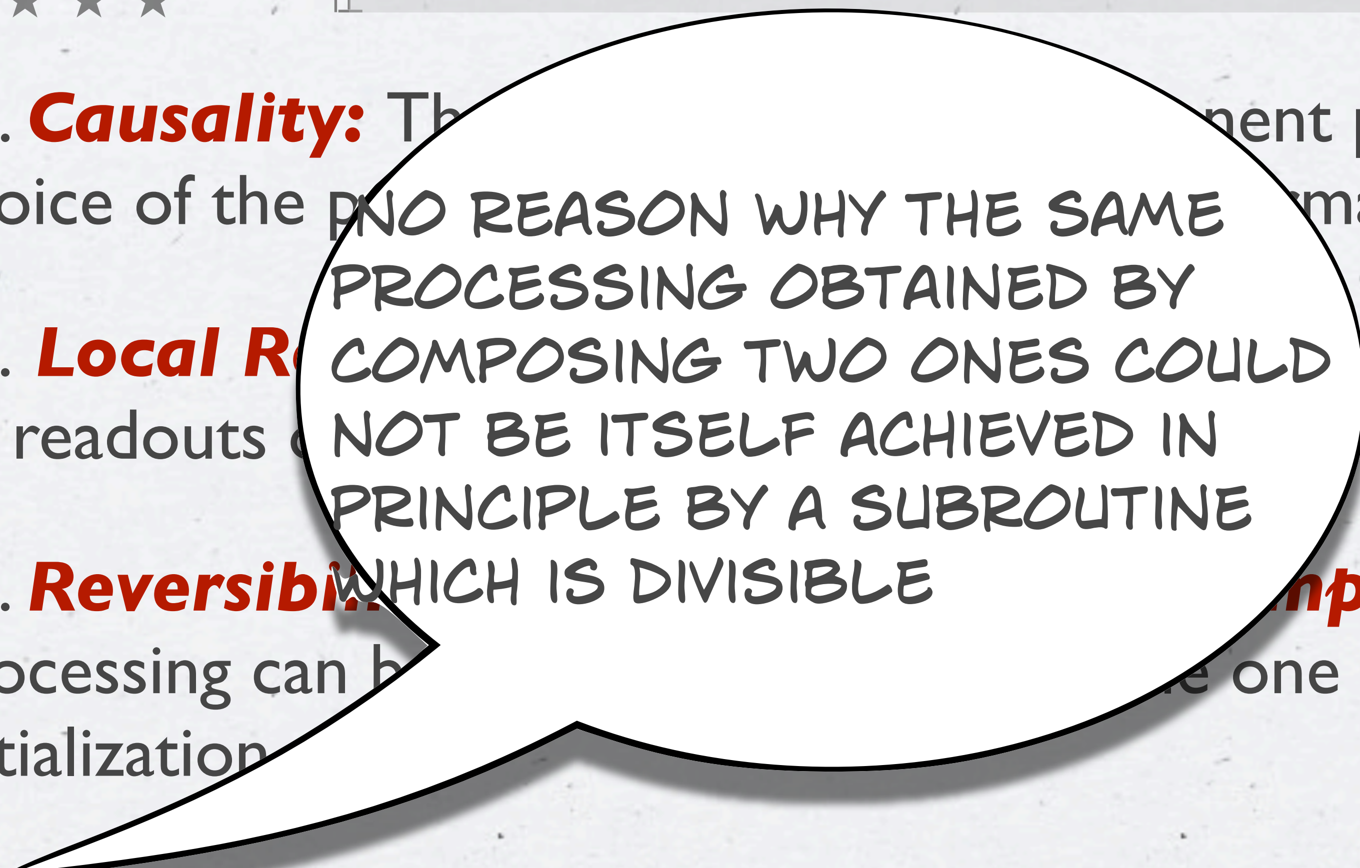
THE PRINCIPLE OF THE QUANTUMNESS

POSTULATES FOR QT

P1. ***Causality:*** Th nent processing cannot depend on the choice of the p mation flows only from input to output).

P2. ***Local R*** vo initializations of multiple registers by readouts

P3. ***Reversibi nputation:*** Every information processing can b e one by adding a register in an indivisible initialization



P4. ***Indivisibility of Processing Composition:*** The processing corresponding to the input-output sequence of two indivisible processings is itself indivisible.

P5. ***Discriminability of Specific Initializations:*** For any specific initialization there exists another initialization that can be perfectly discriminated from it.

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THE PRINCIPLE OF THE QUANTUMNESS

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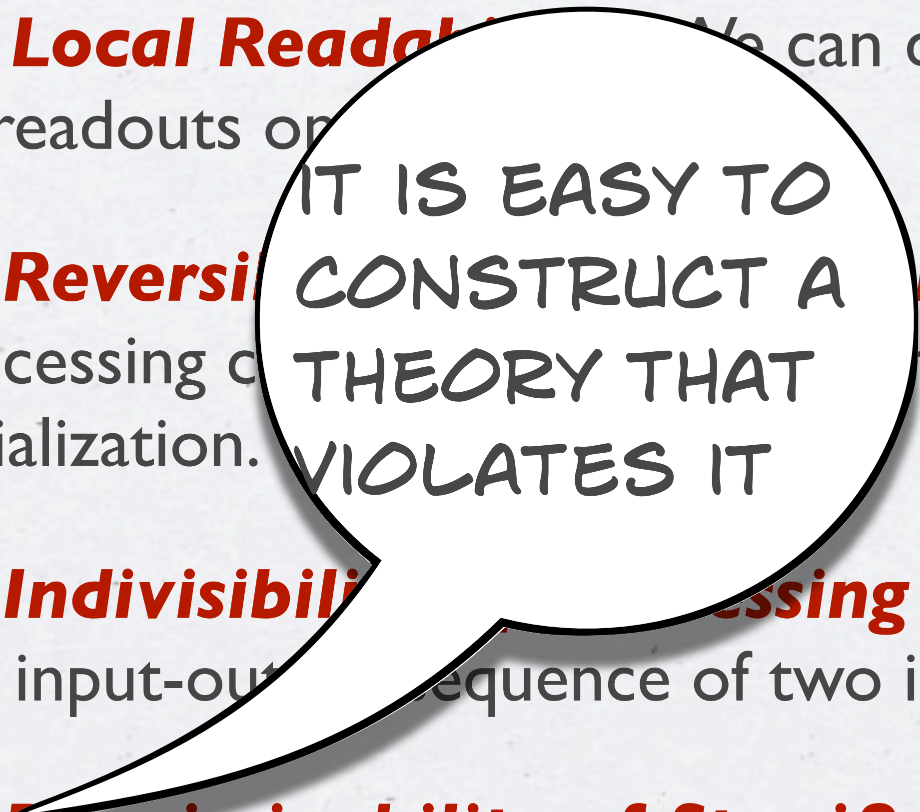

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THE PRINCIPLE OF THE QUANTUMNESS

POSTULATES FOR QT

P1. **C**... ...essing cannot depend on the ch... ...ws only from input to output).

NOT OBVIOUS FOR INFORMATION PROCESSING WITH DIFFERENT KINDS OF REGISTERS

CRUCIAL FOR SHANNON'S & SCHUMAKER'S COMPRESSION

...tions of multiple registers b...

P3. ***Revers*****...** ***...putation:*** Every information processing can be ...ed with a reversible one by adding a register in an indivisible initialization.

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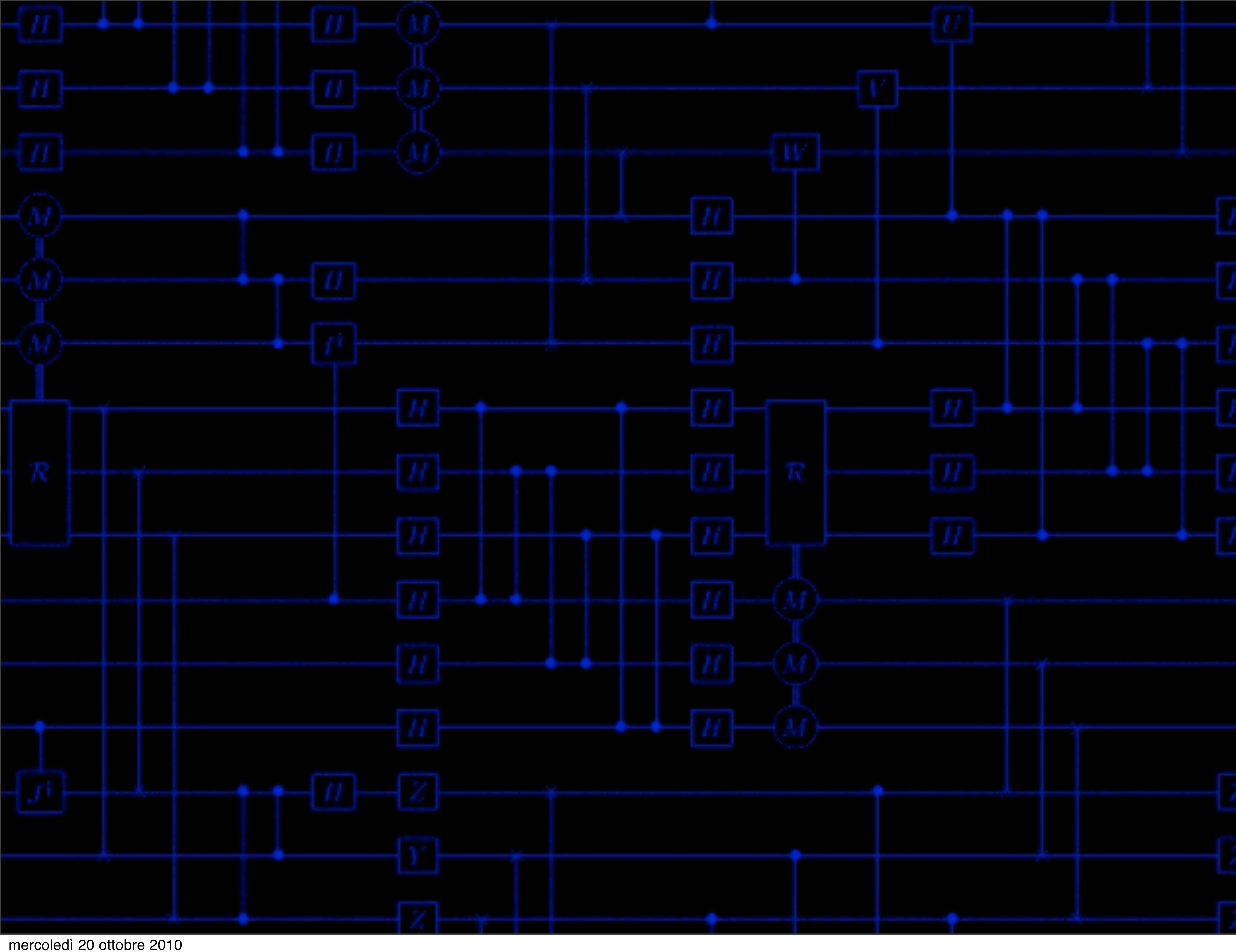
What is out of there?

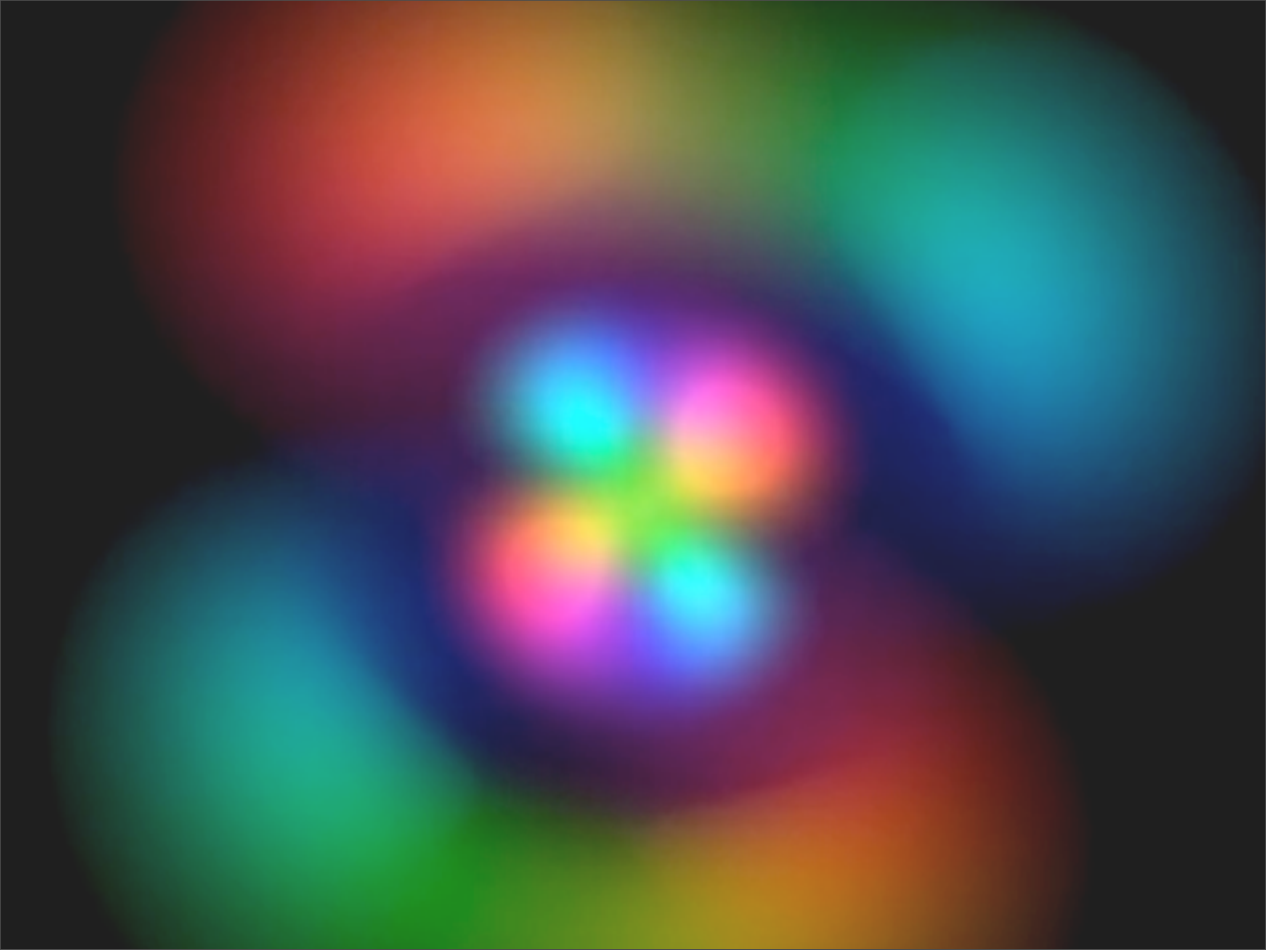

H
M
U
V
W
R
Z
Y

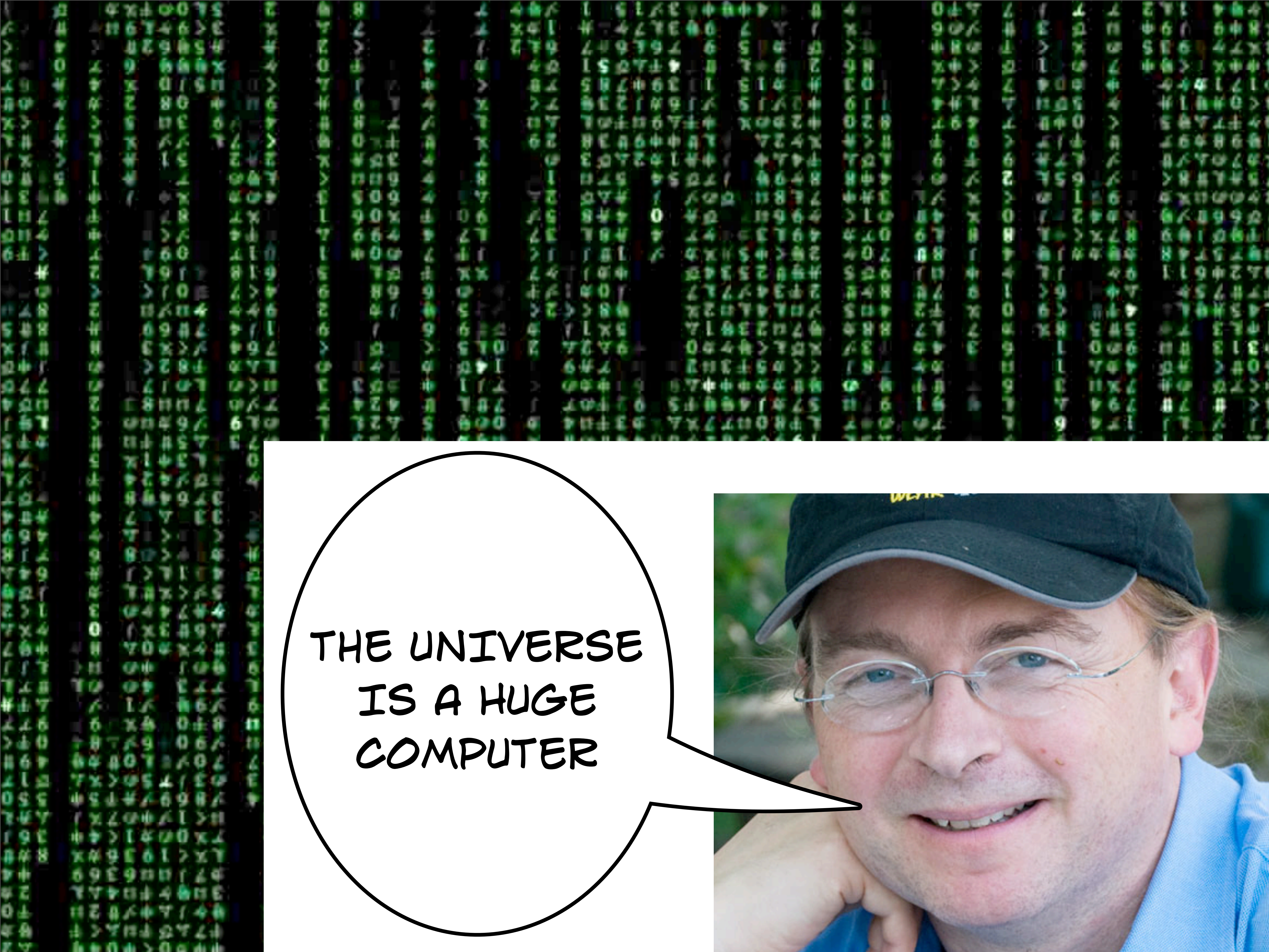
Physics is Information

"It from Bit"

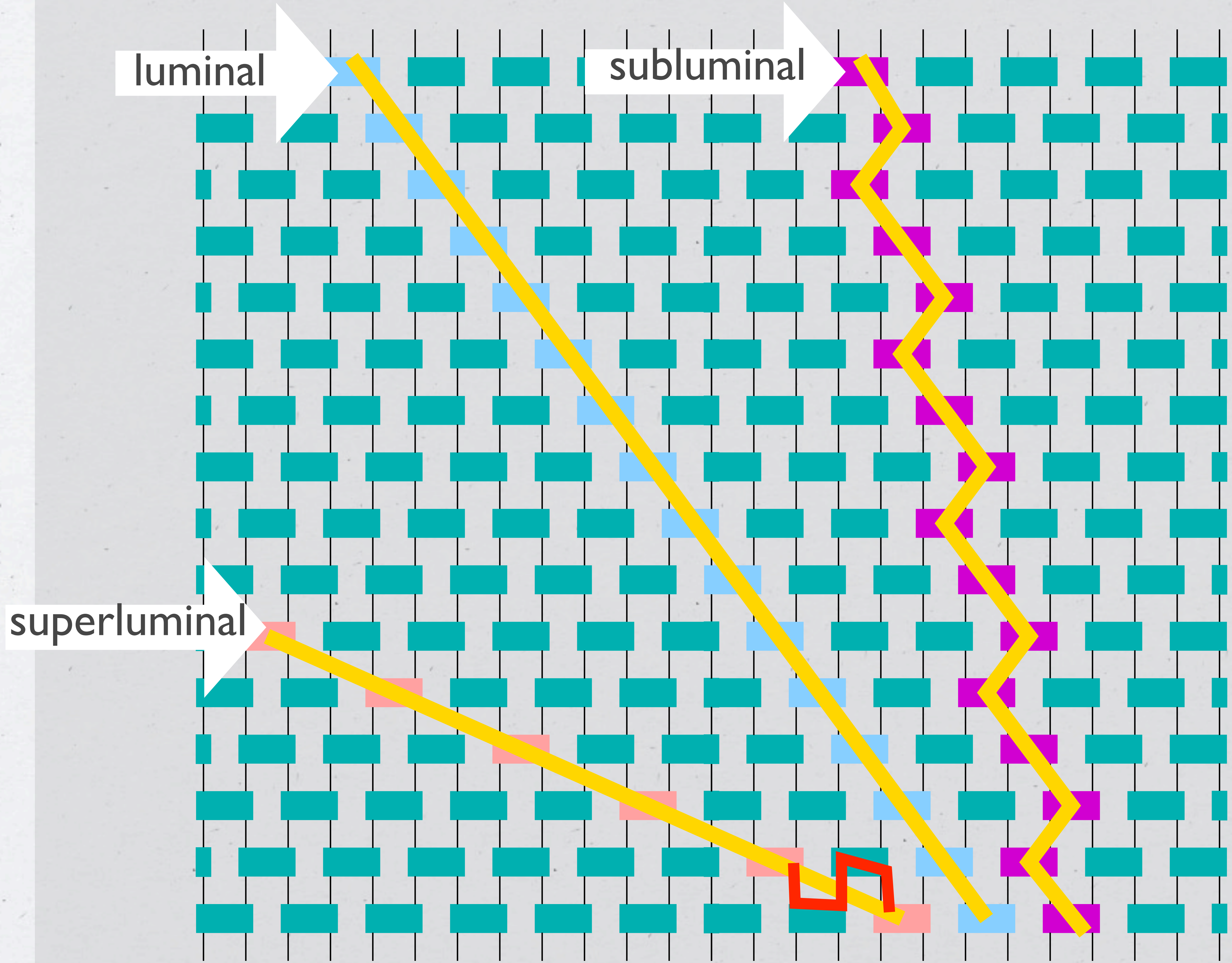
"Information is physical"

(Bit from It)



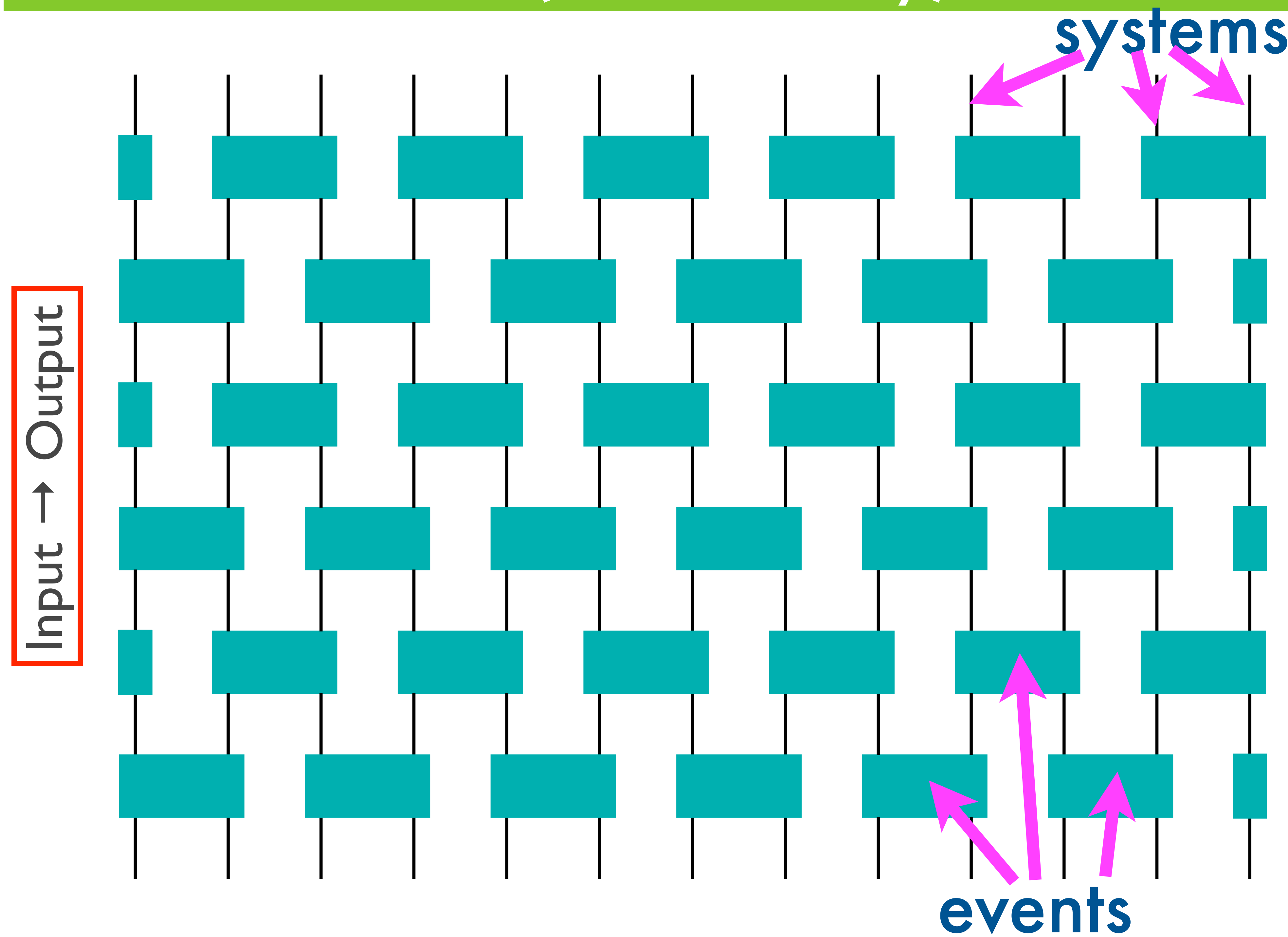

THE UNIVERSE
IS A HUGE
COMPUTER

HOW RELATIVITY EMERGES FROM THE COMPUTATION?


luminal
subluminal
superluminal

Relativity from QT

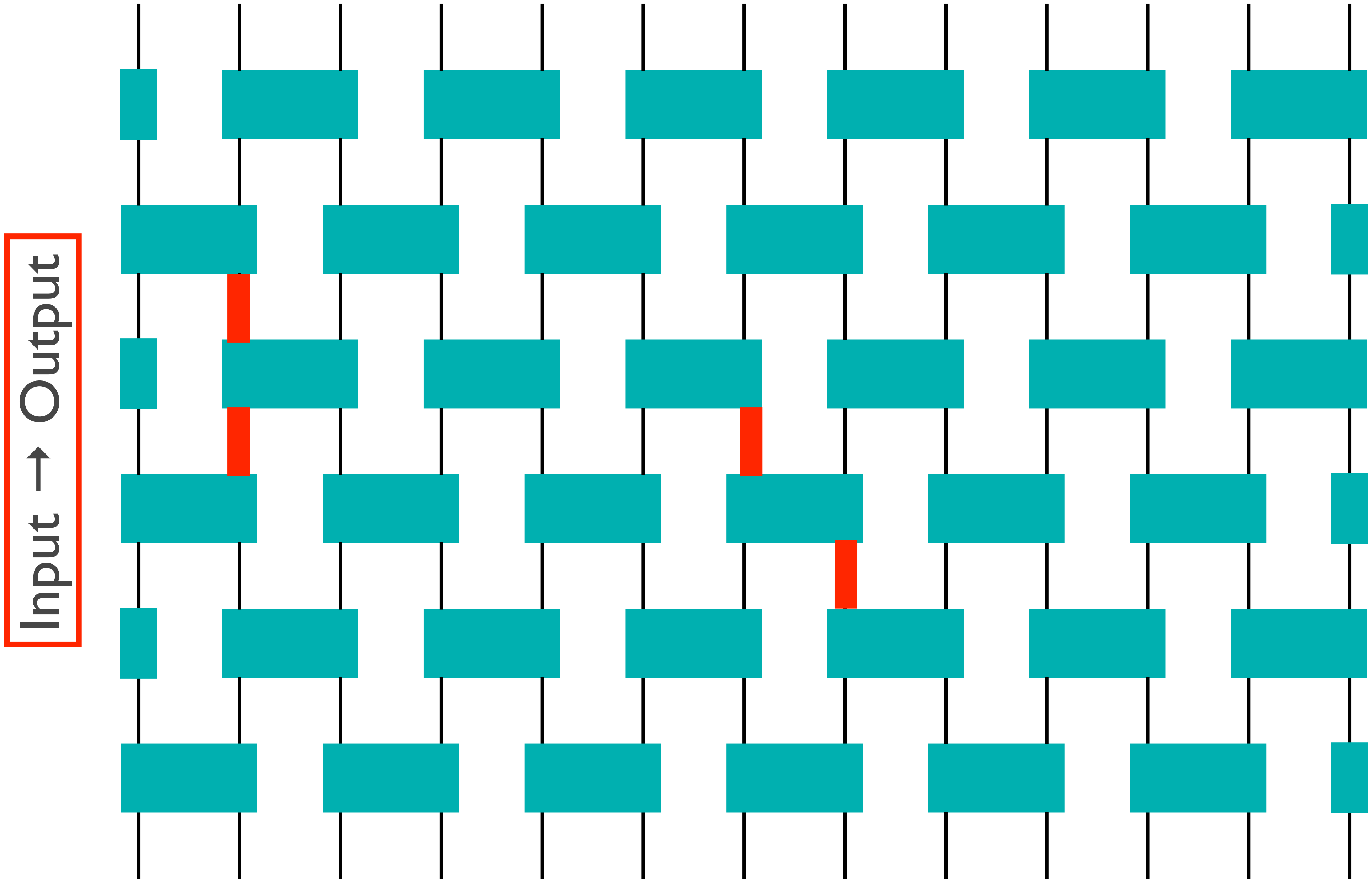
(from causality)



Relativity from QT

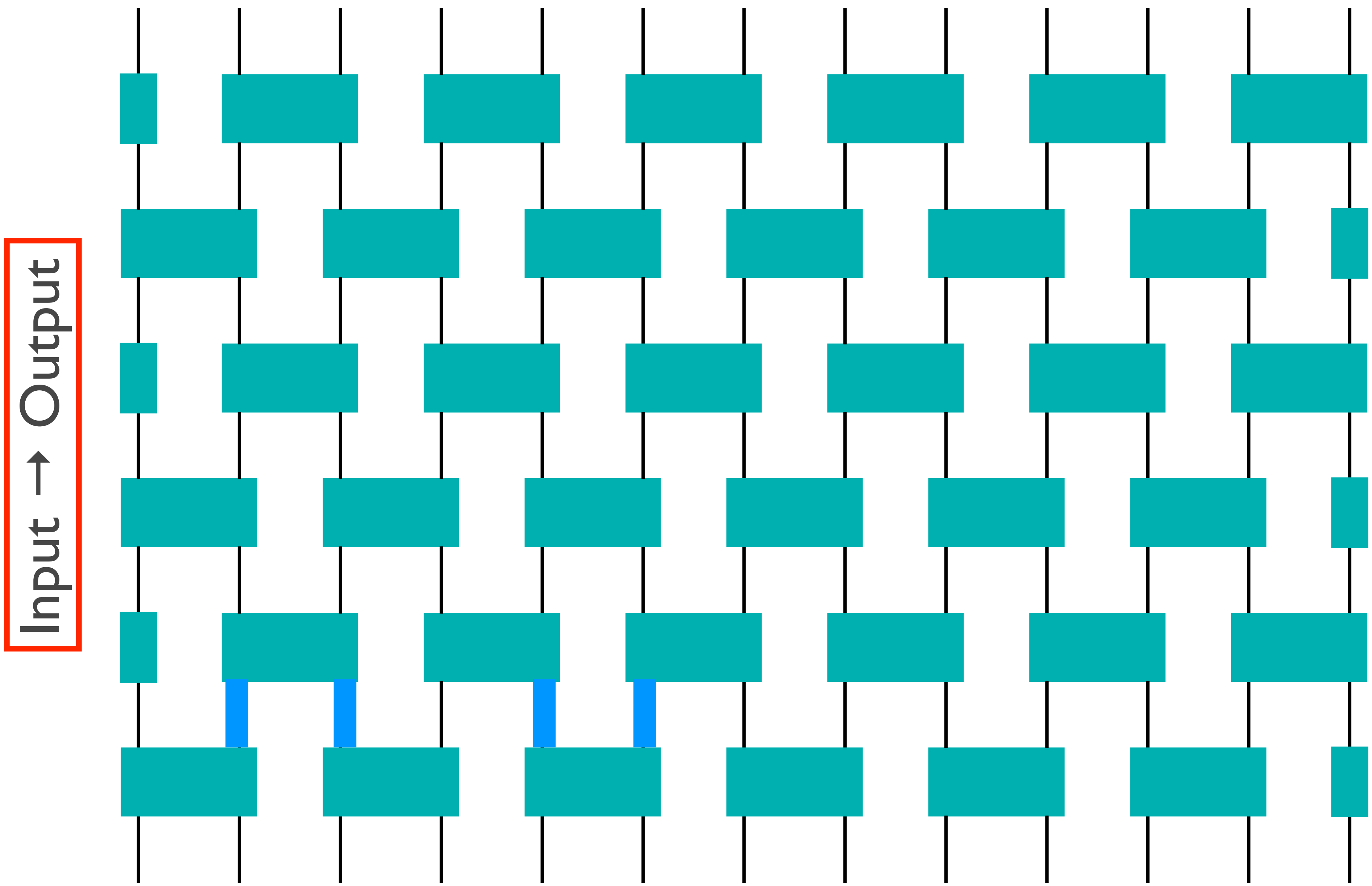
(from causality)

causally connected systems



Relativity from QT

(from causality)



independent systems

"slice"

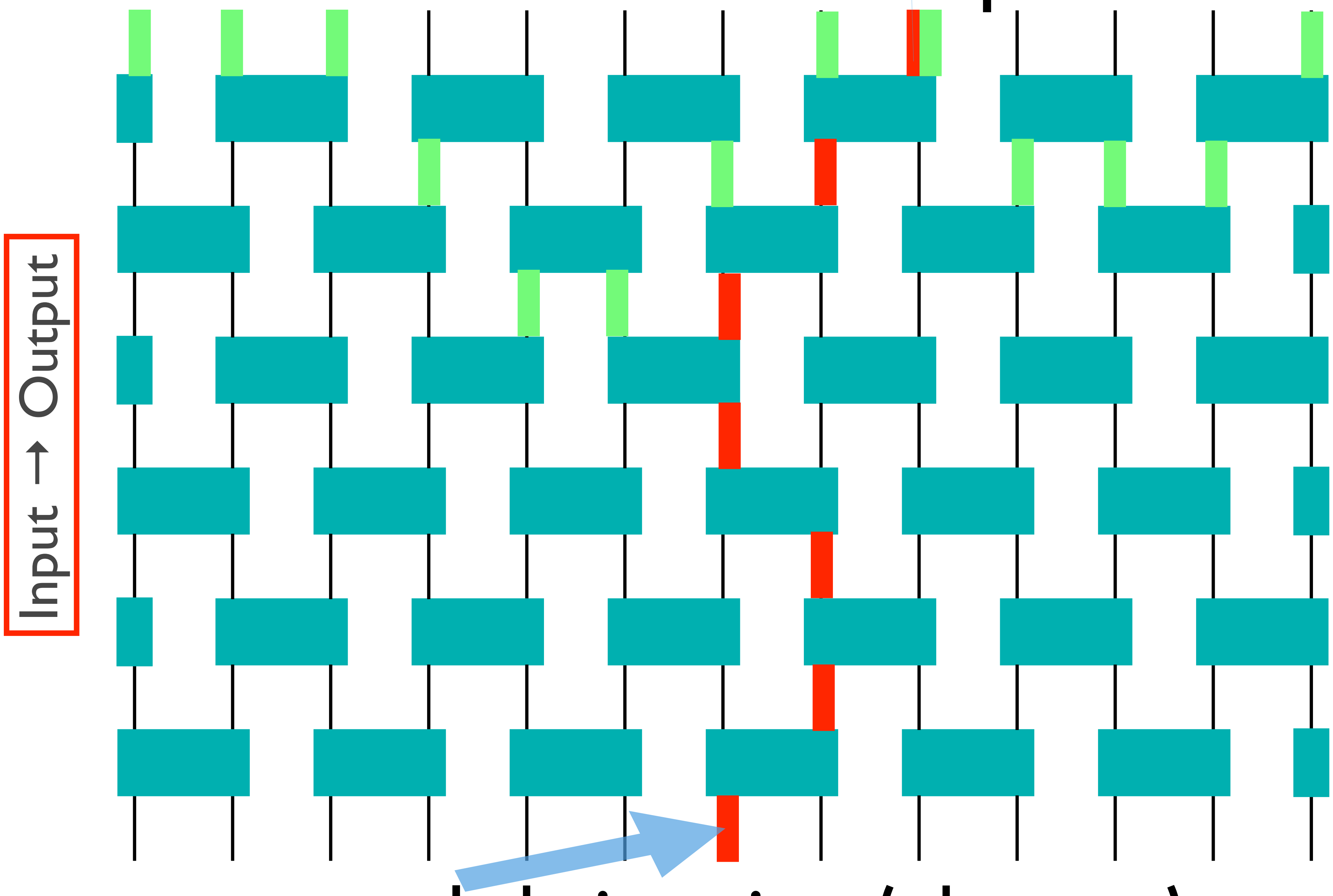
Relativity from QT

(from causality)

topology (Alexandrov)

metric = event-counting

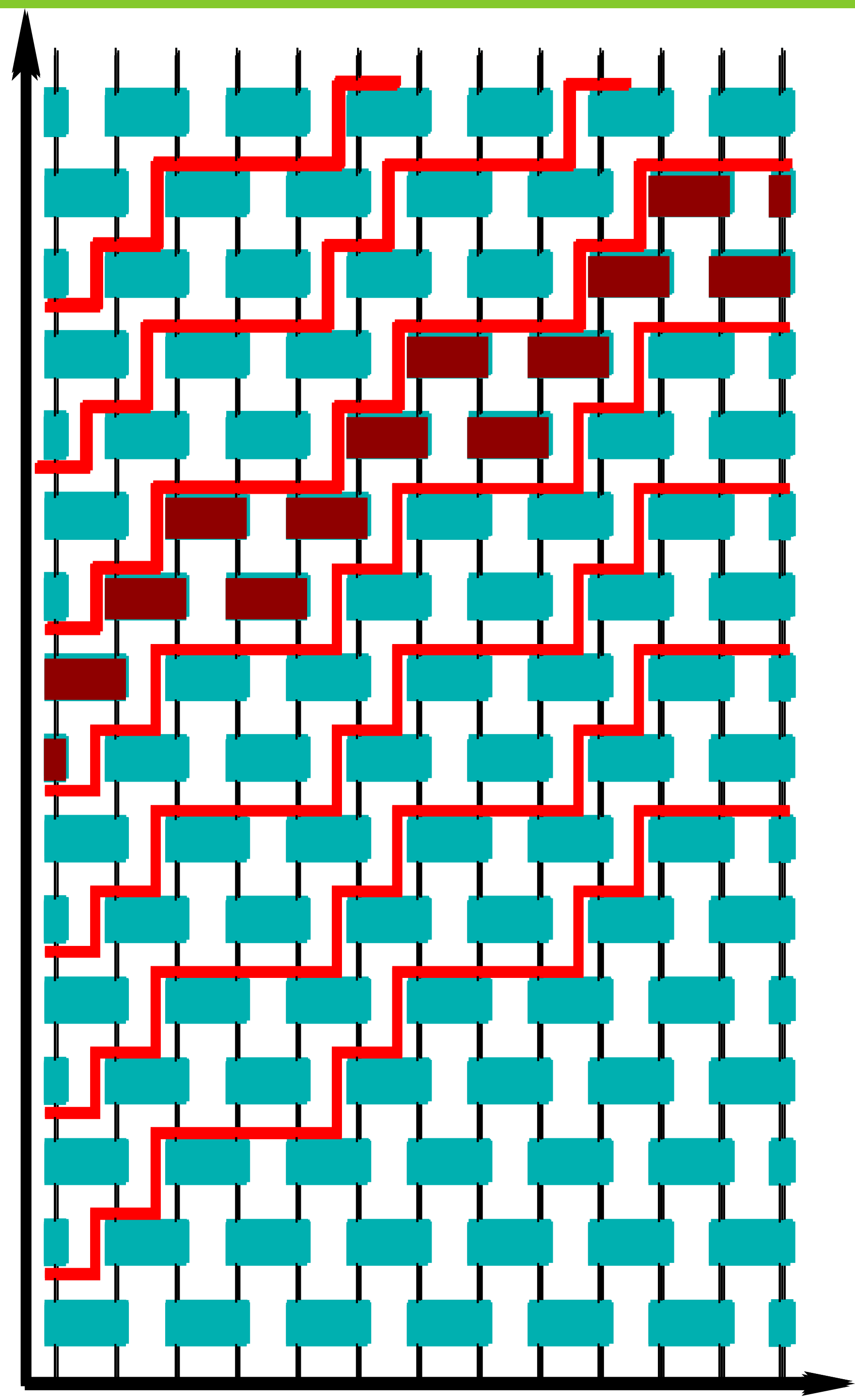
causal antichain = space



causal chain = time (observer)

Relativity from QT

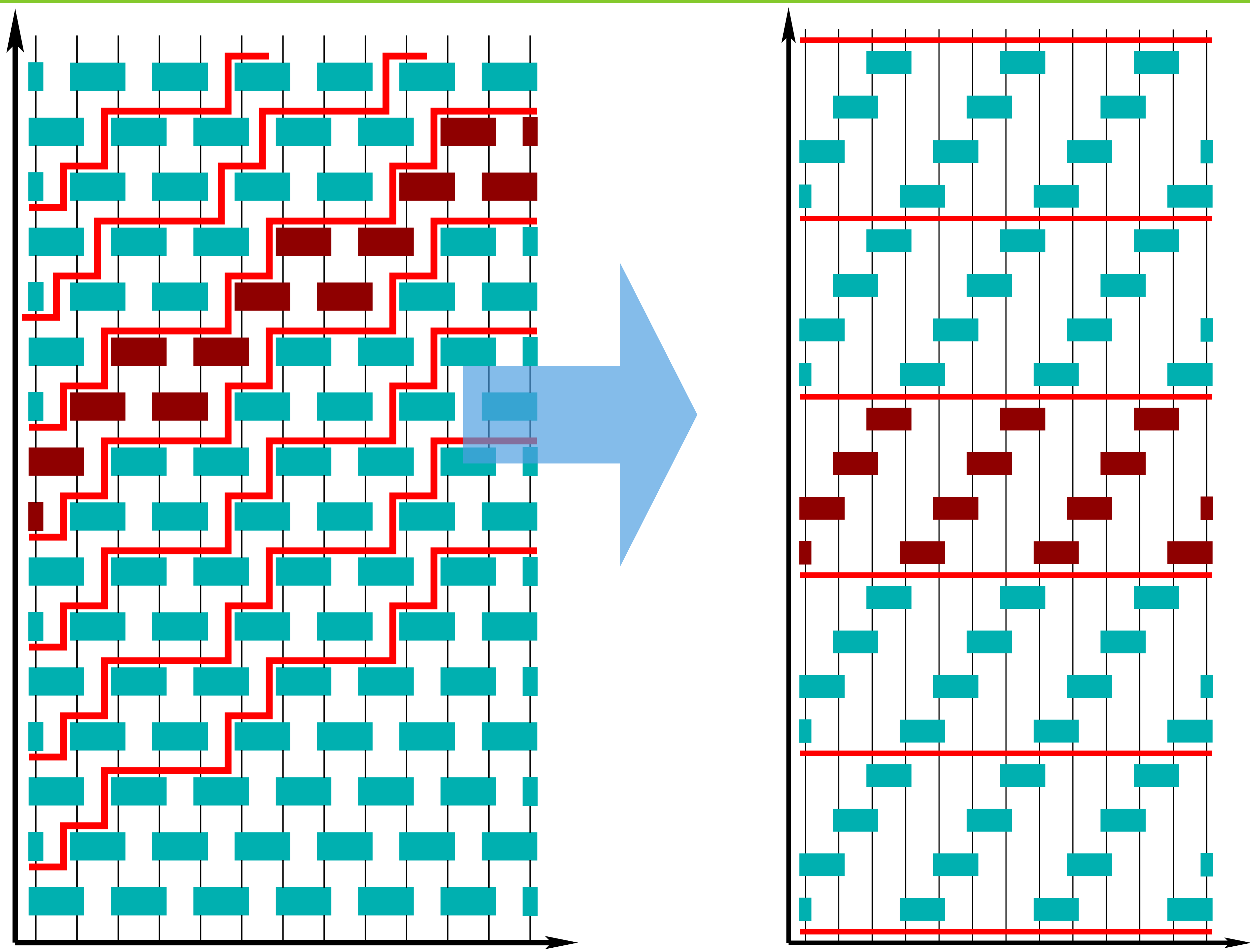
(from causality)



build a uniform foliation

Relativity from QT

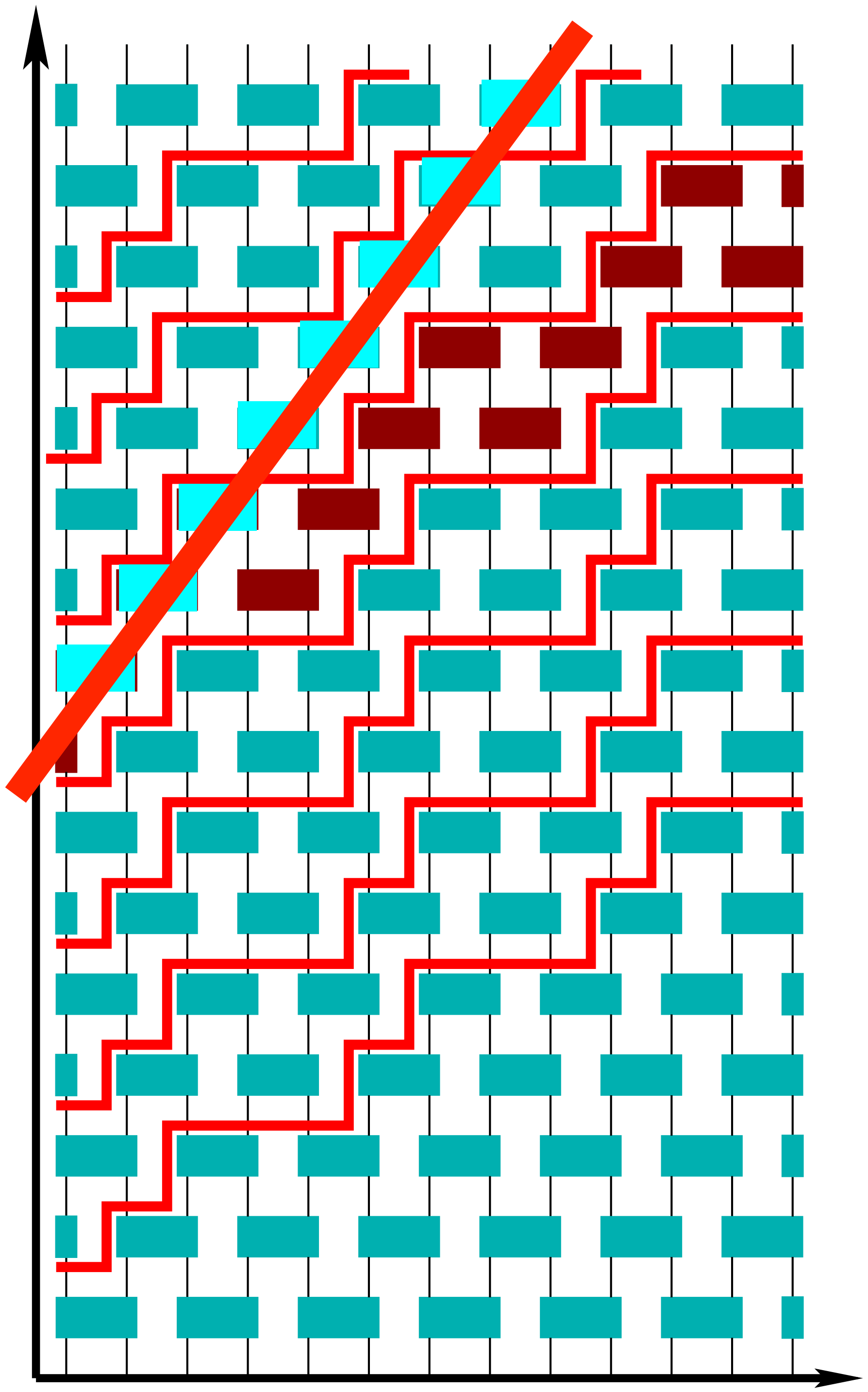
(from causality)



change reference

Relativity from QT

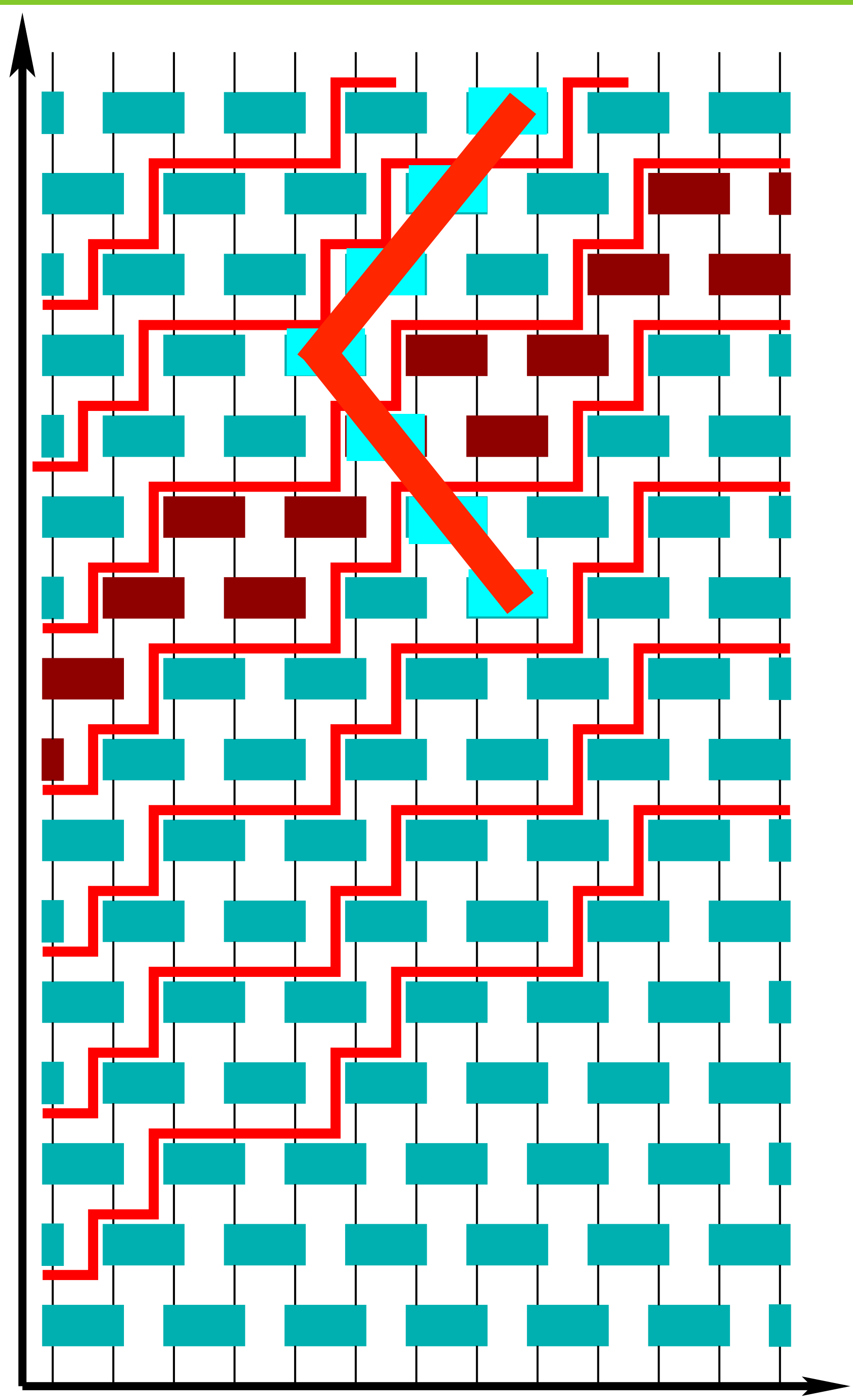
(from causality)



speed of light

Relativity from QT

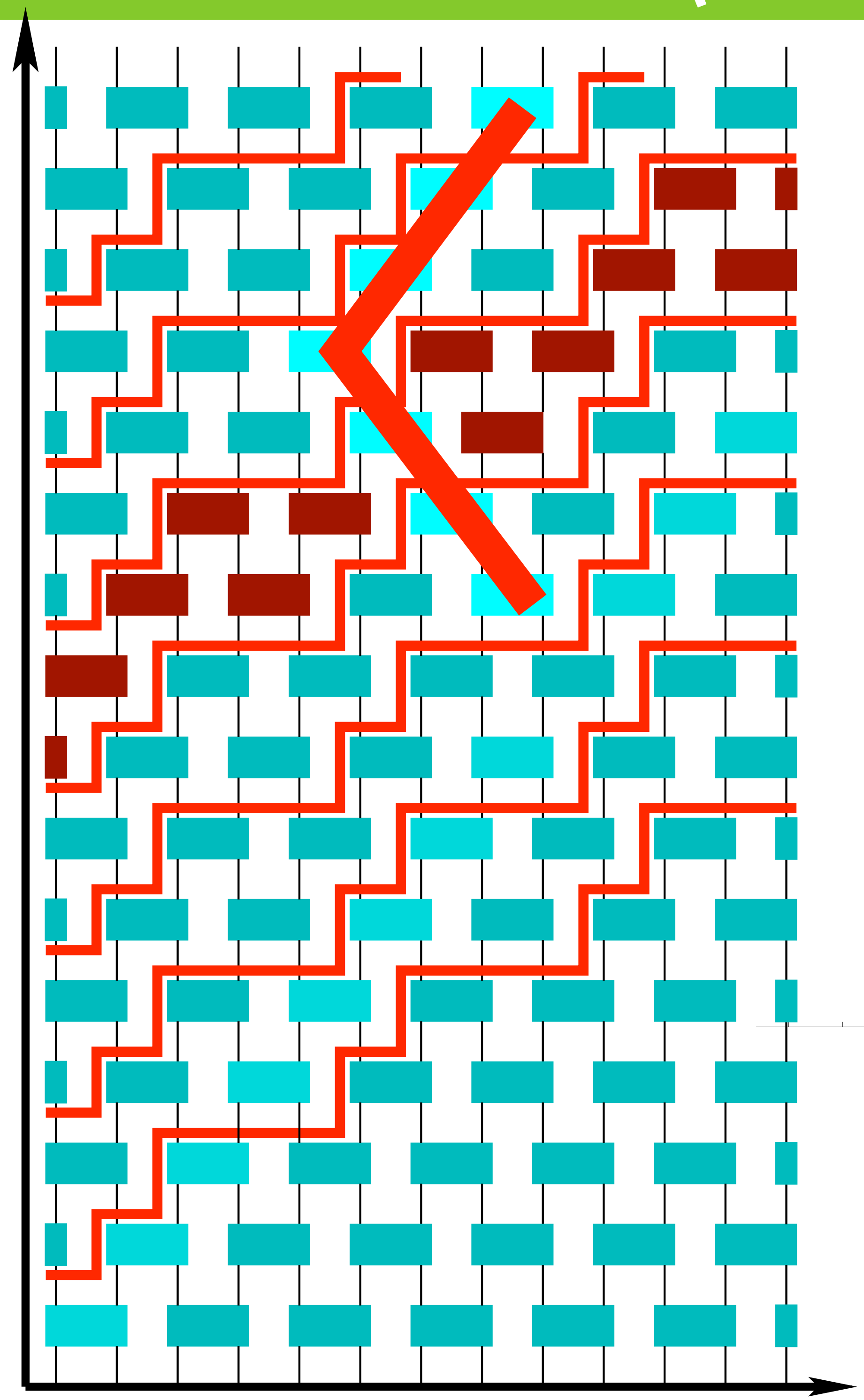
(from causality)

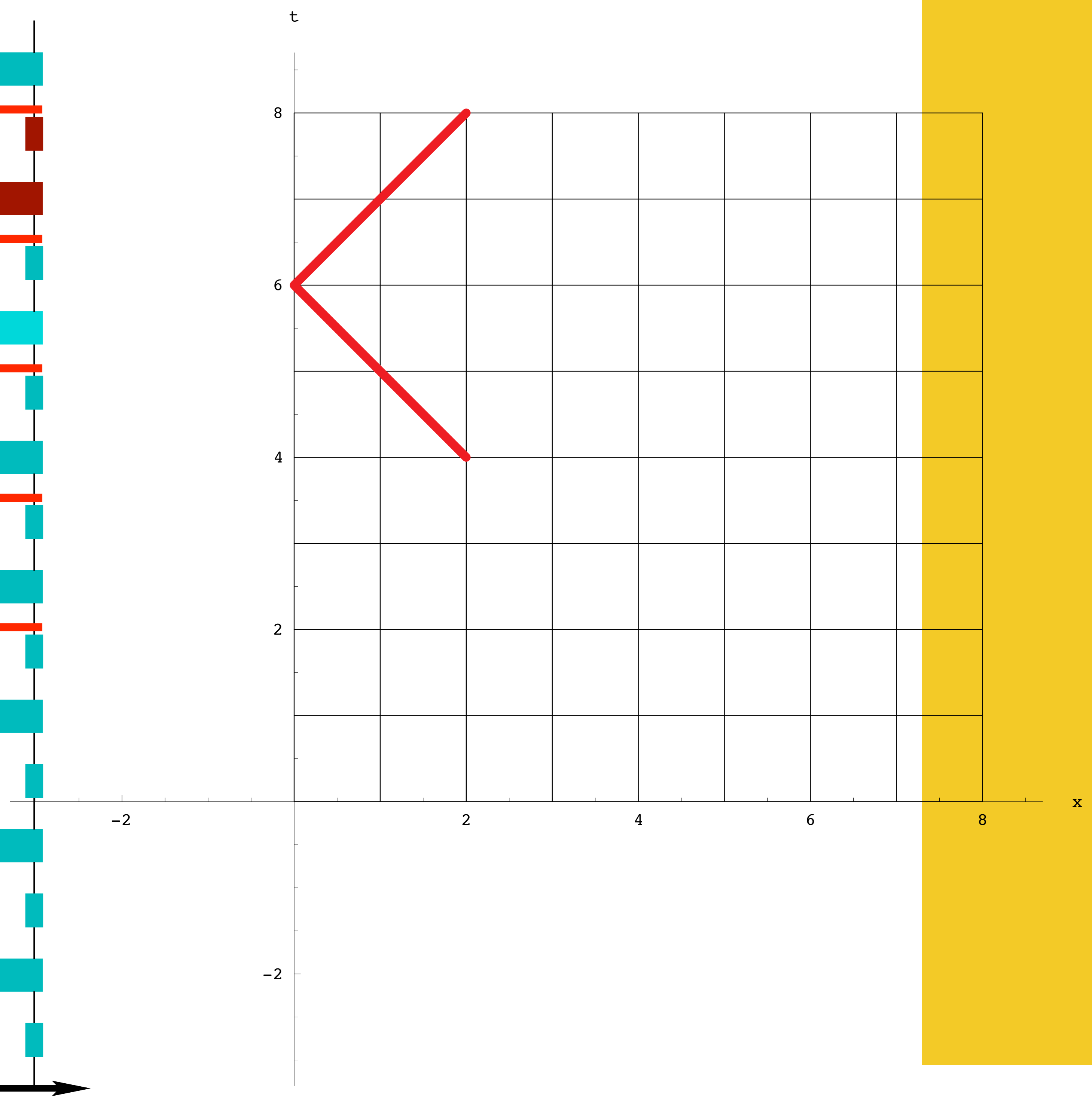


clock tic-tac

Relativity from QT

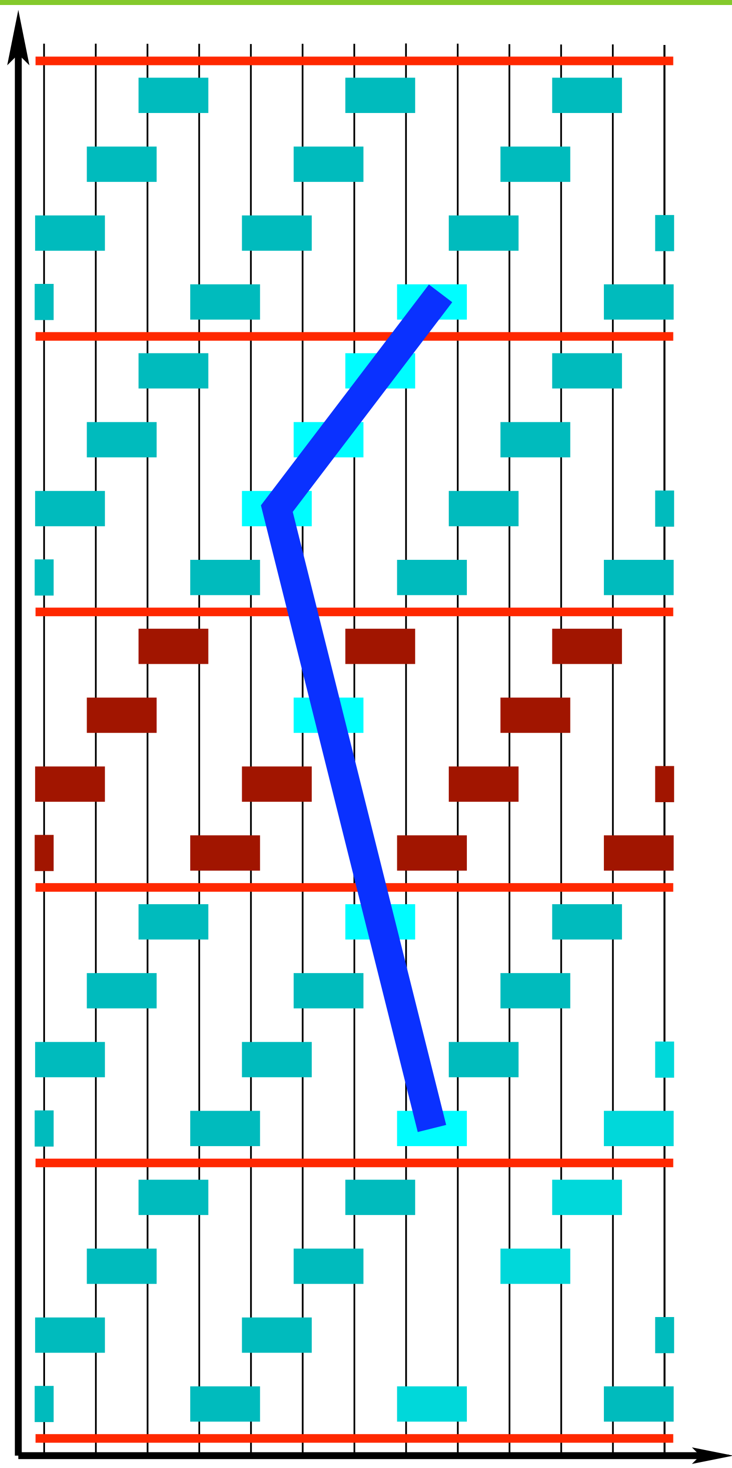
(from causality)

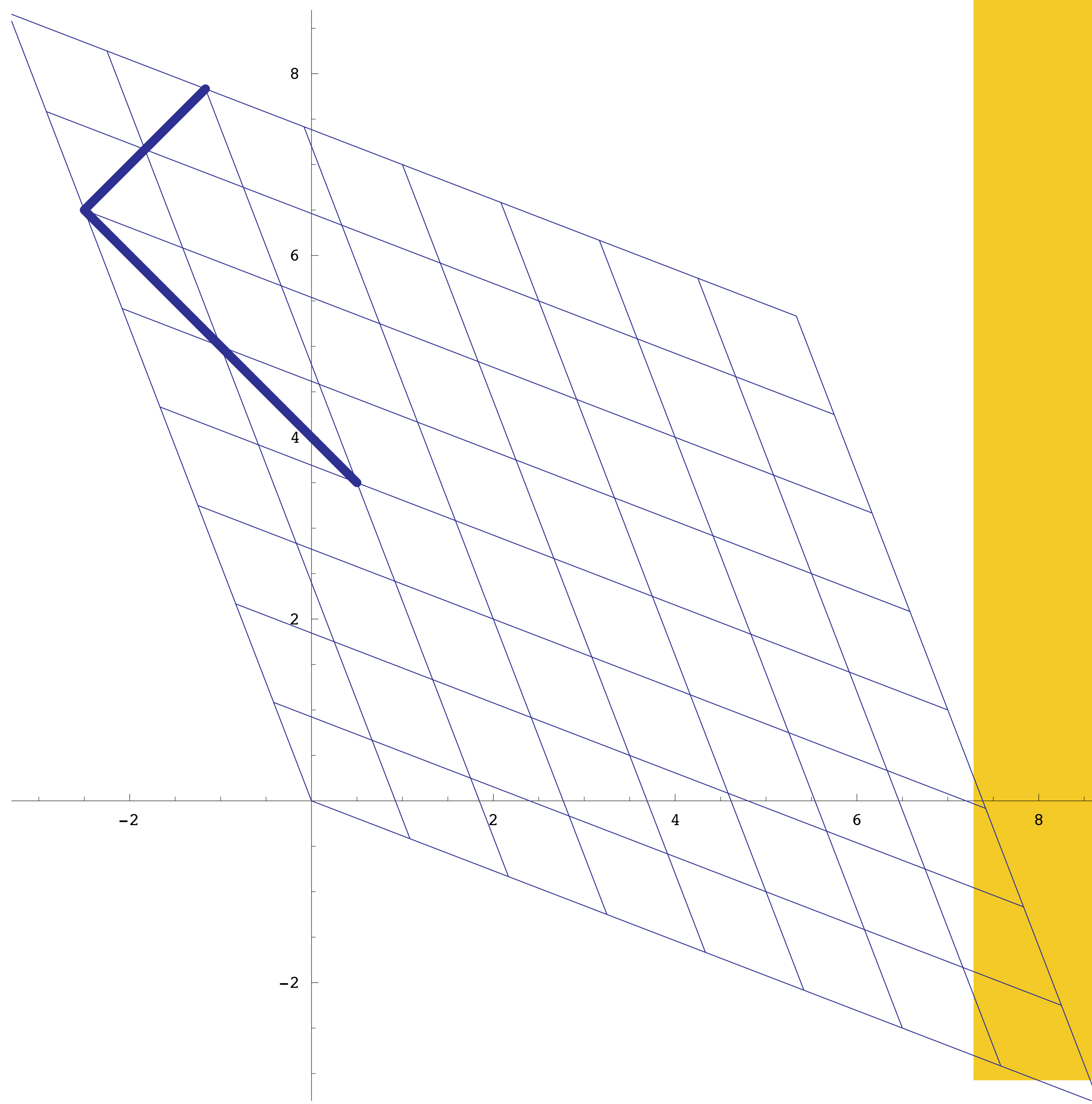


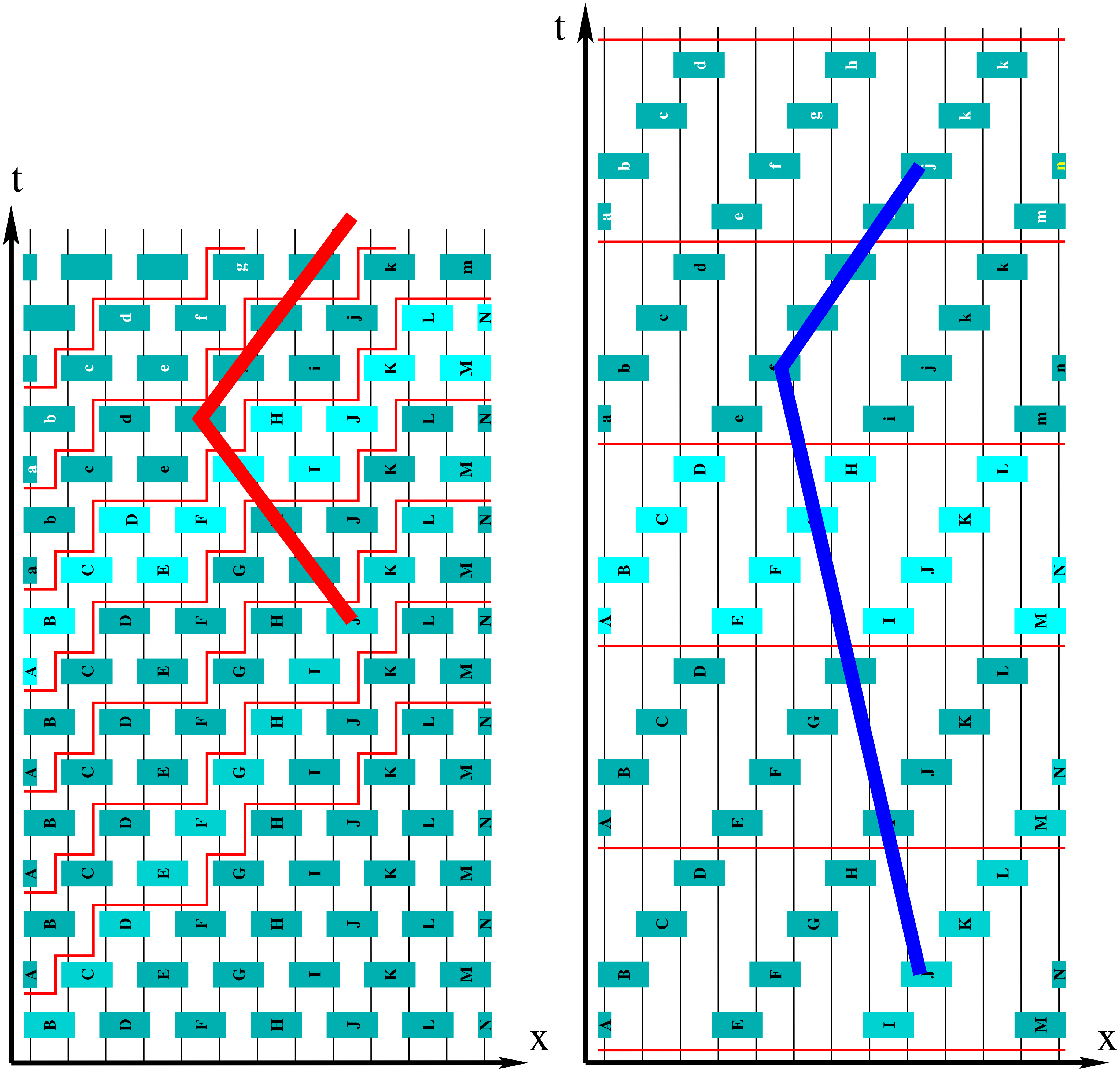


Relativity from QT

(from causality)



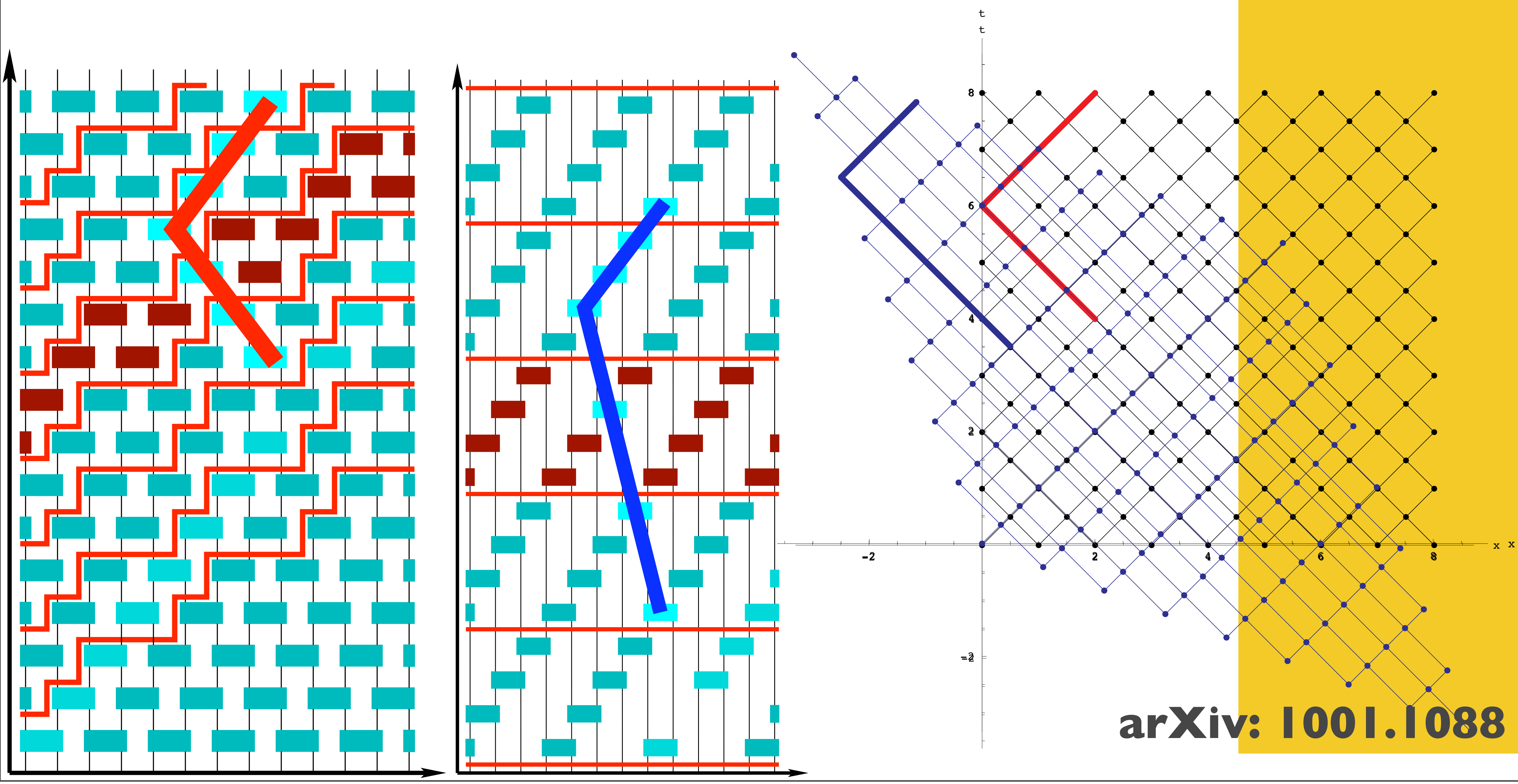




Time dilation and space contraction

Relativity from QT

(from causality)



arXiv: 1001.1088

WE GOT RELATIVITY FROM CAUSALITY!

WE GOT MUCH MORE:

FROM CAUSALITY WE GOT SPACE AND TIME ENDOWED WITH RELATIVITY!

Relativity from QT

A theory of quantum gravity based on quantum computation

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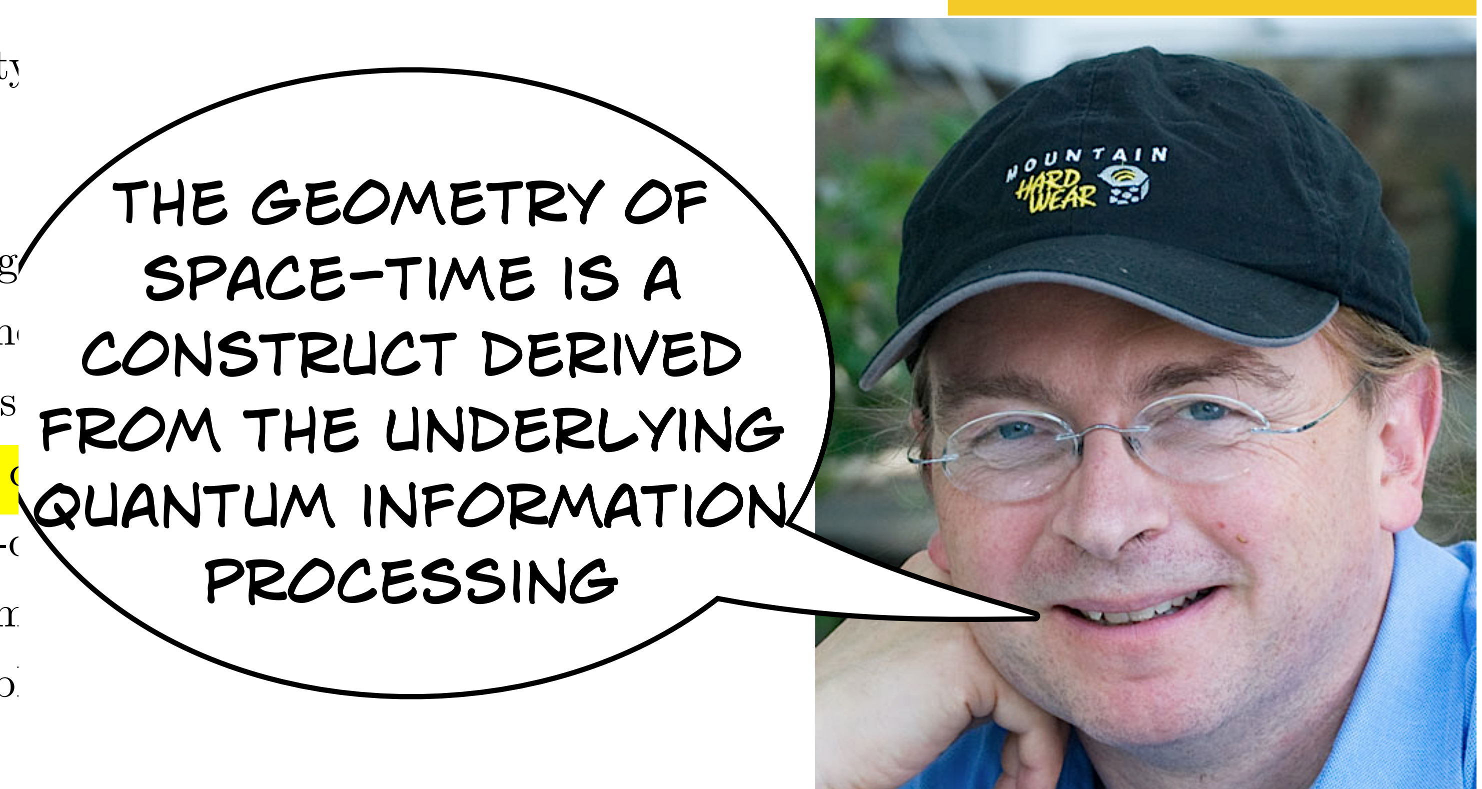
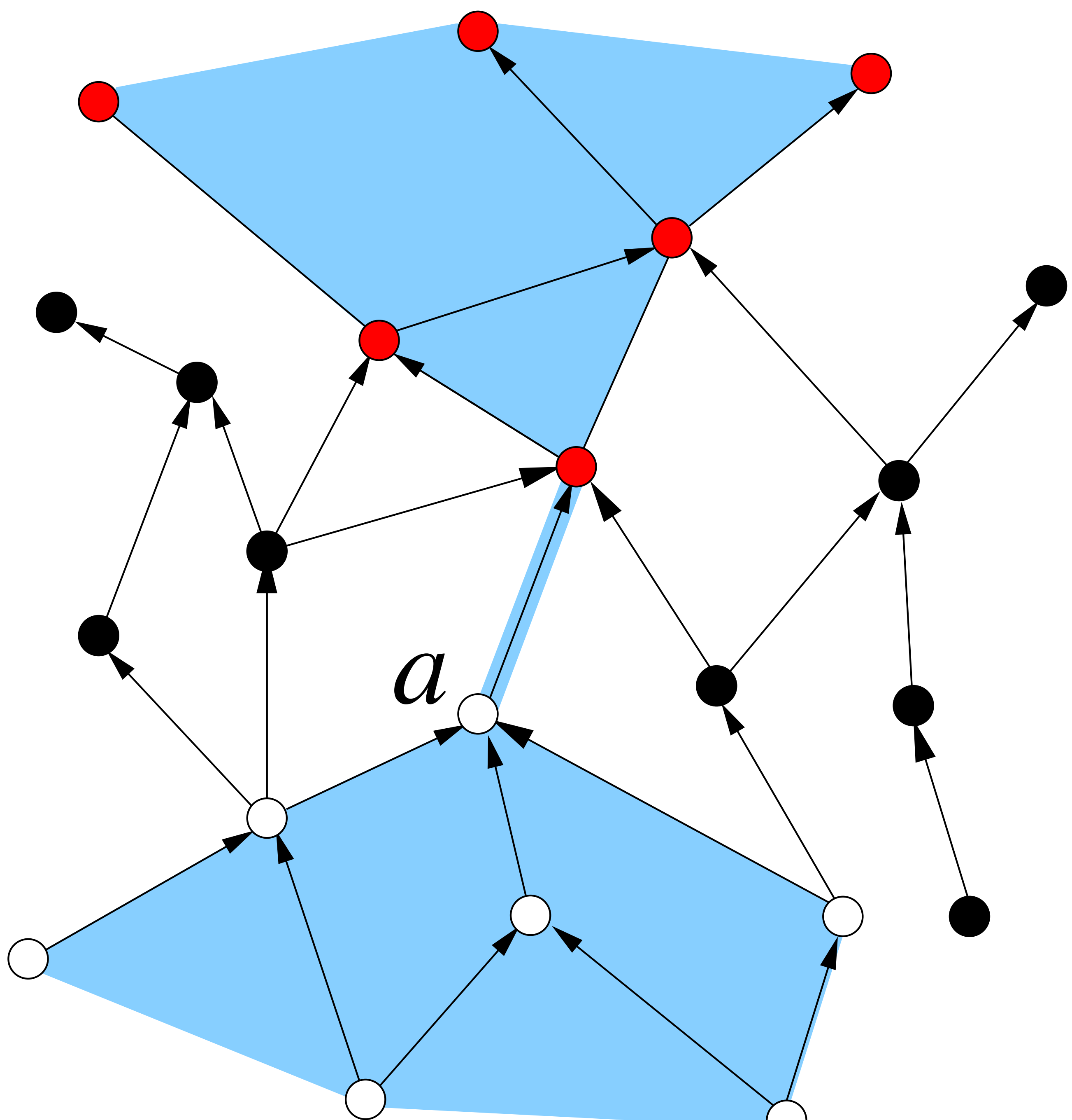
Keywords: quantum computation, quantum gravity

Abstract: This paper proposes a method of unifying
on quantum computation. In this theory, fundam
of pairwise interactions between quantum degrees
time is a construct, derived from the underlying
computation gives rise to a superposition of four-
obeys the Einstein-Regge equations. The theory m
reaction of the metric to computational 'matter,' b
quantum cosmology.



Lorentz transformations from causality and topological homogeneity

GMD and
A. Tosini
1008.4805



"Light" cones

Lorentz transformations from causality and topological homogeneity

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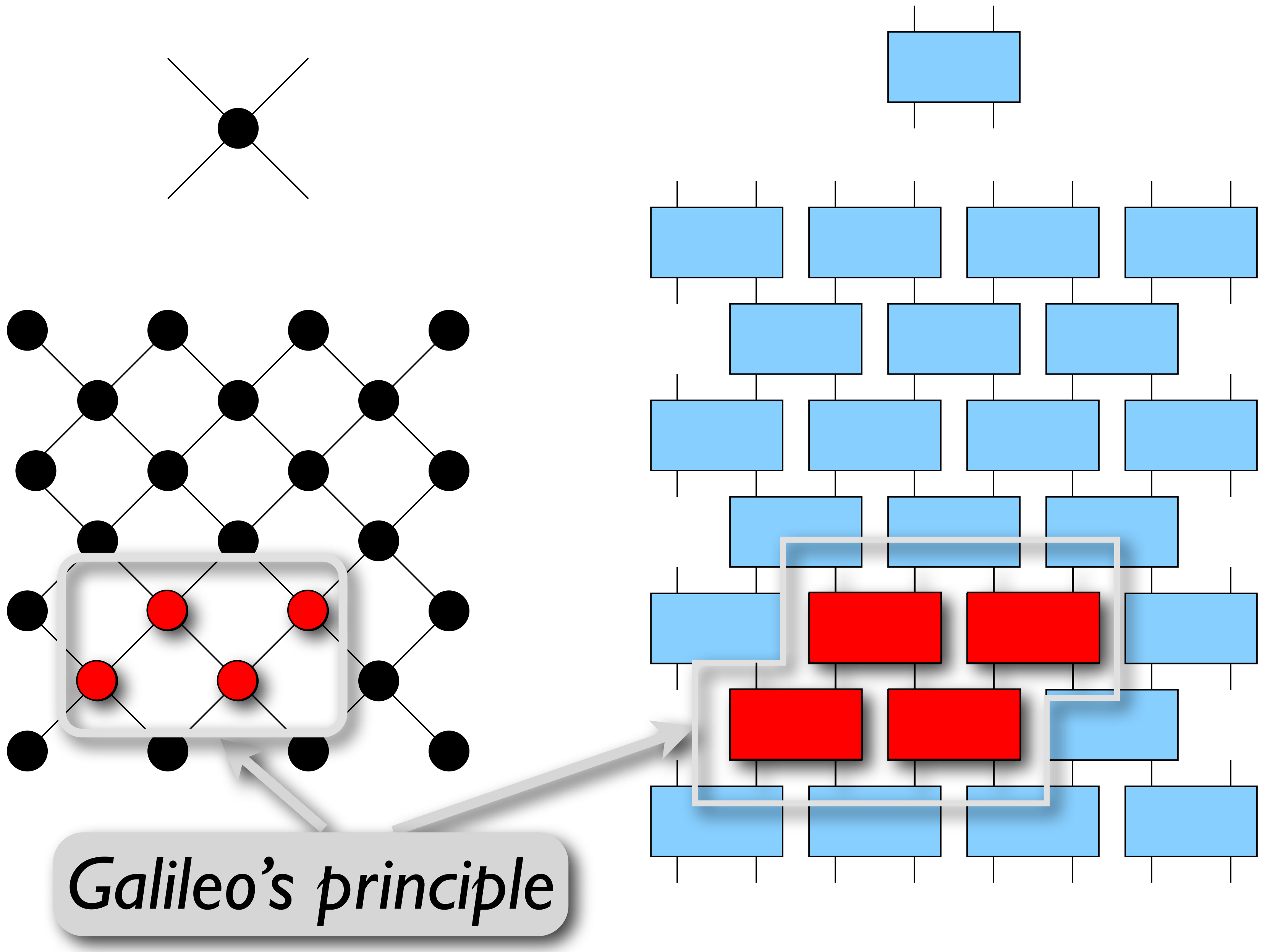
topological homogeneity



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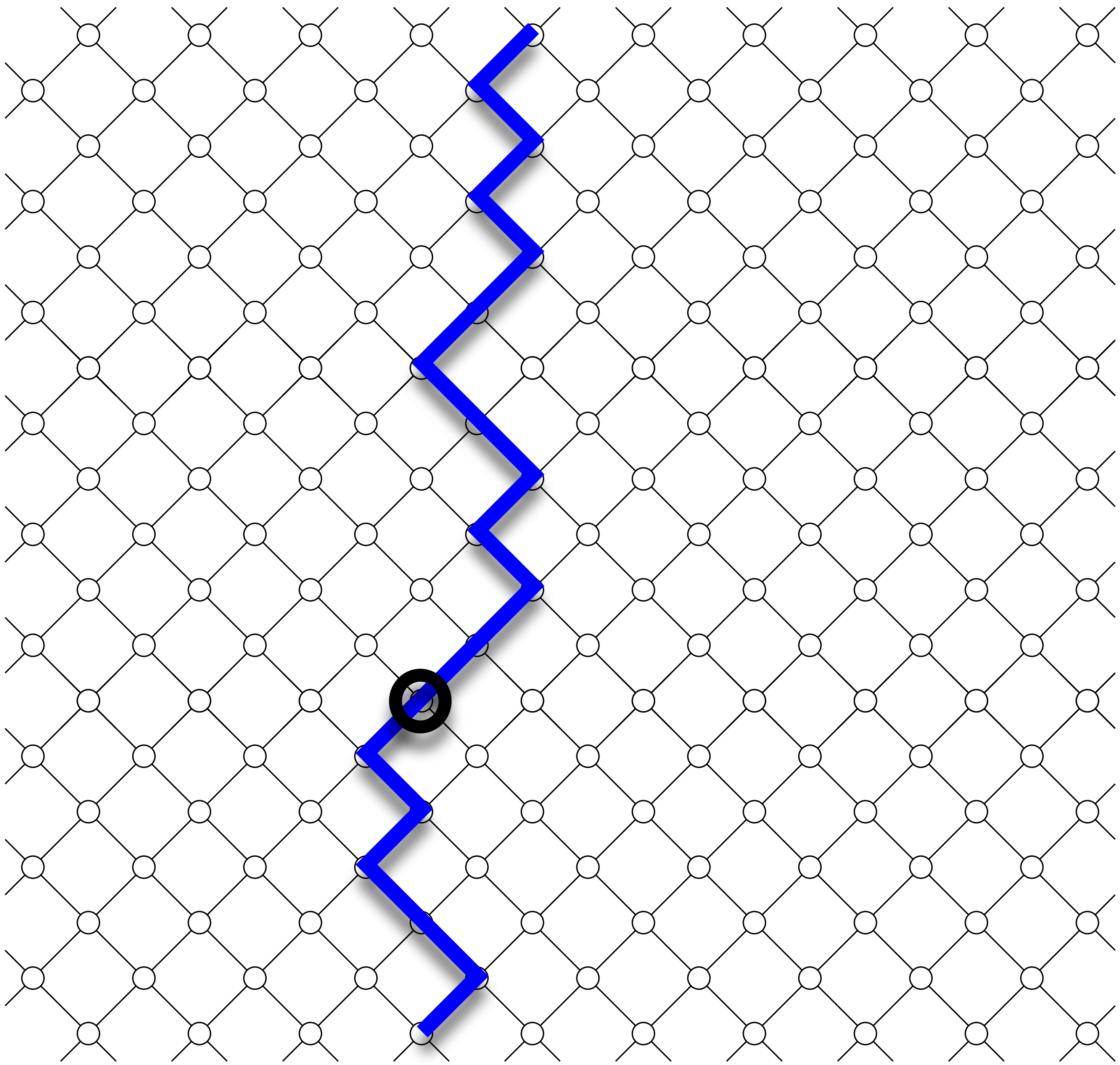

observer

Lorentz transformations from causality and topological homogeneity

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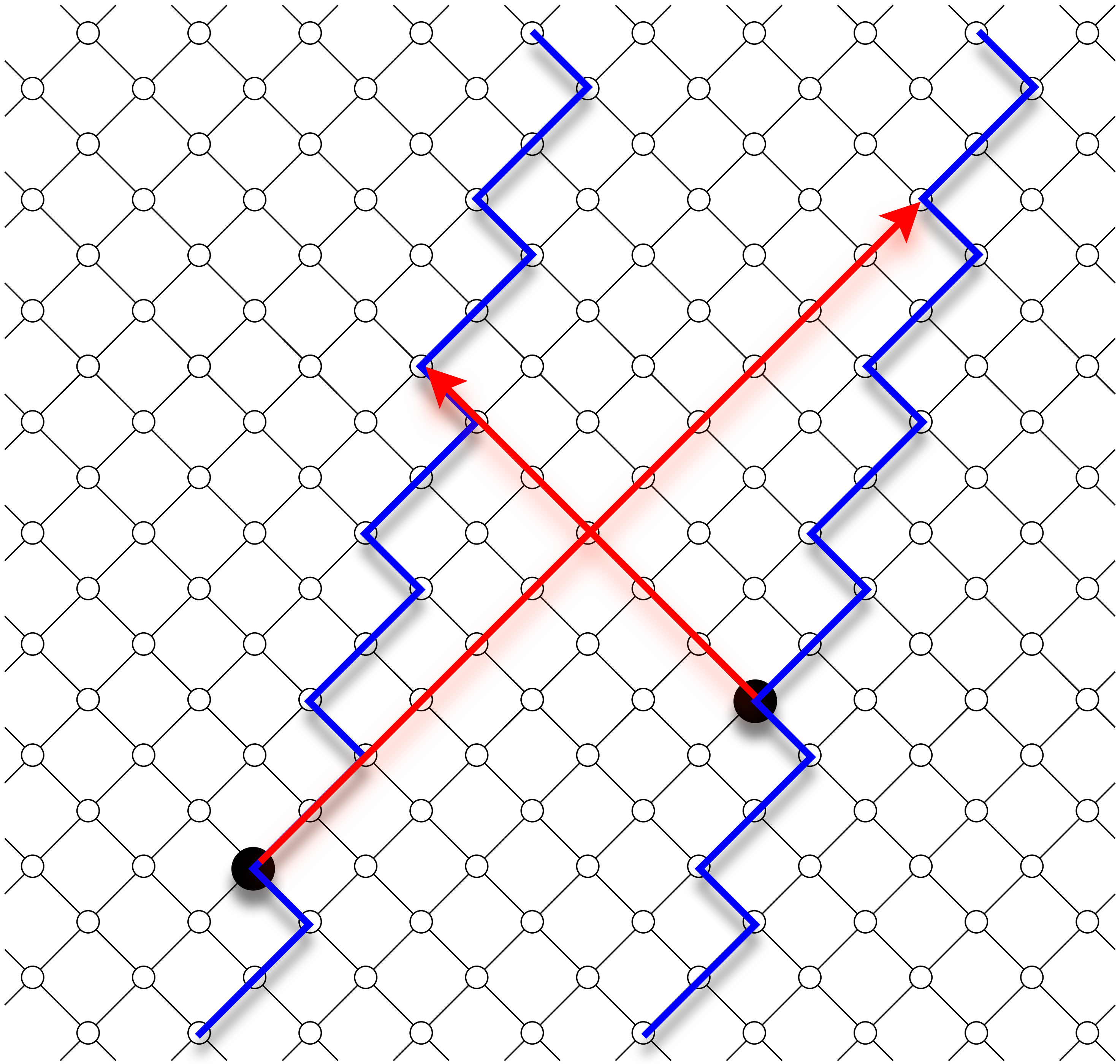

Simultaneity

Lorentz transformations from causality and topological homogeneity

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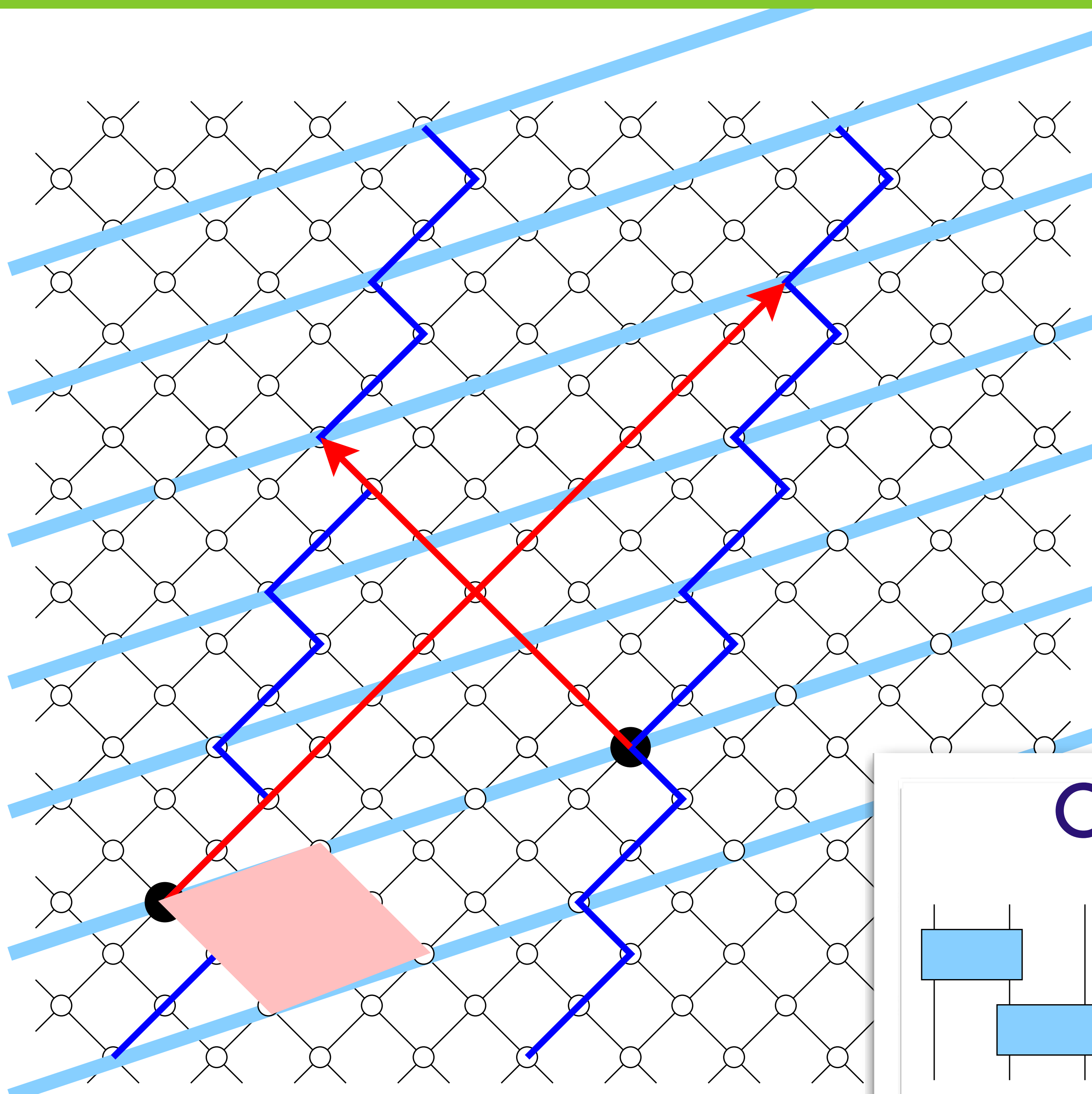
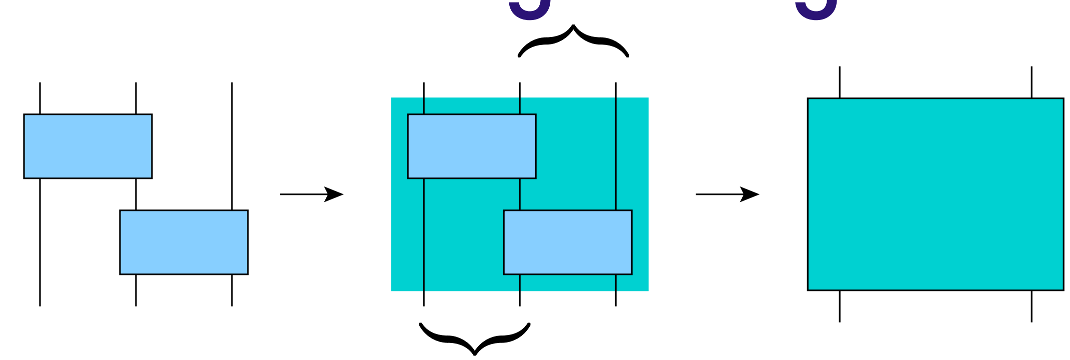


oliation

Coarse-graining



Lorentz transformations from causality and topological homogeneity

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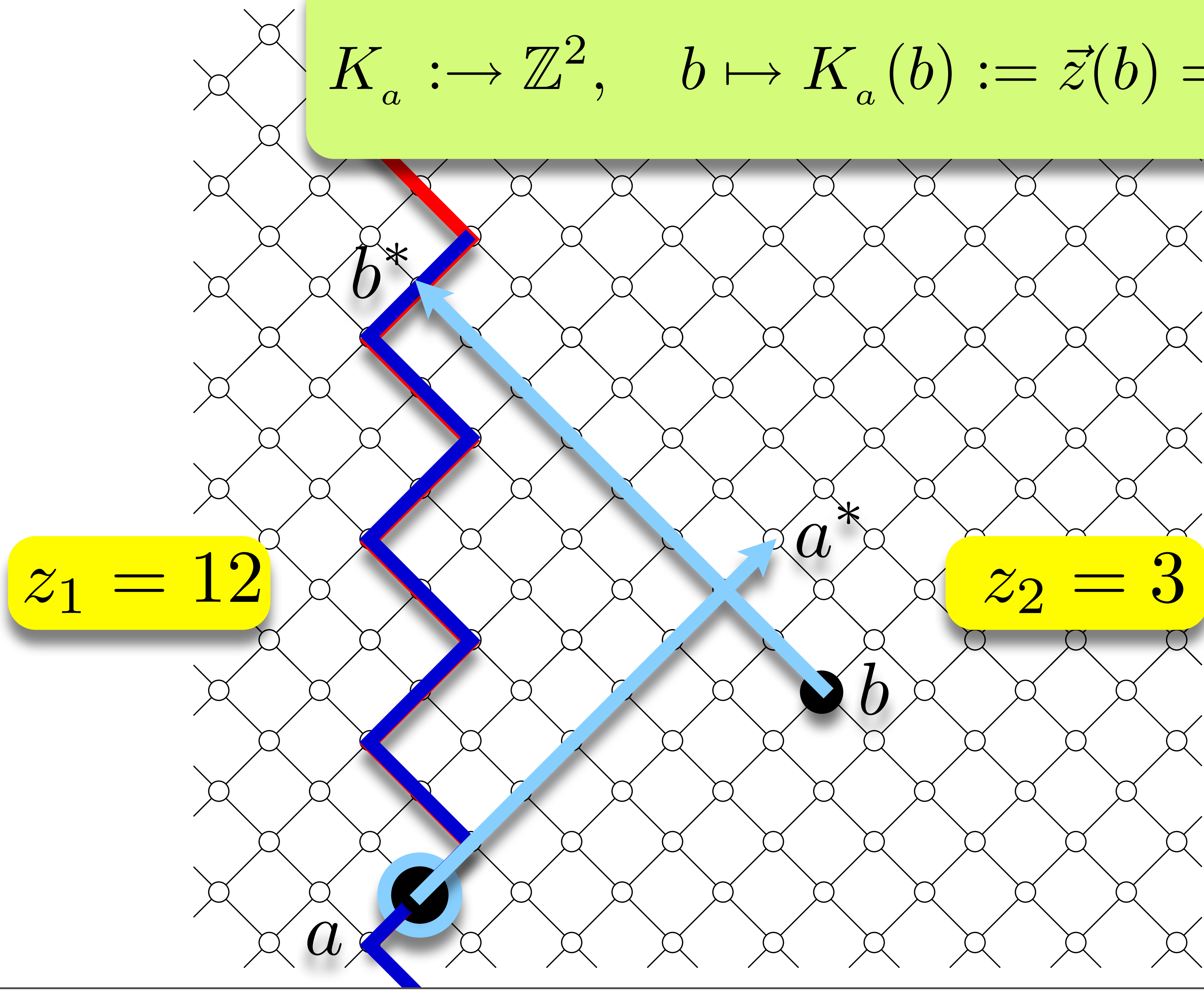
1008.4805

$$K_a :\longrightarrow \mathbb{Z}^2, \quad b \mapsto K_a(b) := \vec{z}(b) = \begin{bmatrix} z_1(b) \\ z_2(b) \end{bmatrix}$$



Coordinates

Lorentz transformations from causality and topological homogeneity

GMD and
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1008.4805

Coordinates

Lemma 1 *An event* $b \in \mathsf{L}(\mathsf{O}_a)$ *belongs to the* t*-th leaf* $\mathsf{L}_t(\mathsf{O}_a)$ *for* $t = (z_1 - z_2)/2$*, and the number of events on such leaf between* b *and* O_a *is given by* $s = (z_1 + z_2)/2$*.*

According to the last Lemma the coordinates

$$\begin{bmatrix} t(b) \\ s(b) \end{bmatrix} := 2^{\frac{1}{2}} \mathbf{U}(\pi/4) \begin{bmatrix} z(b) \\ z(b) \end{bmatrix}, \tag{10}$$

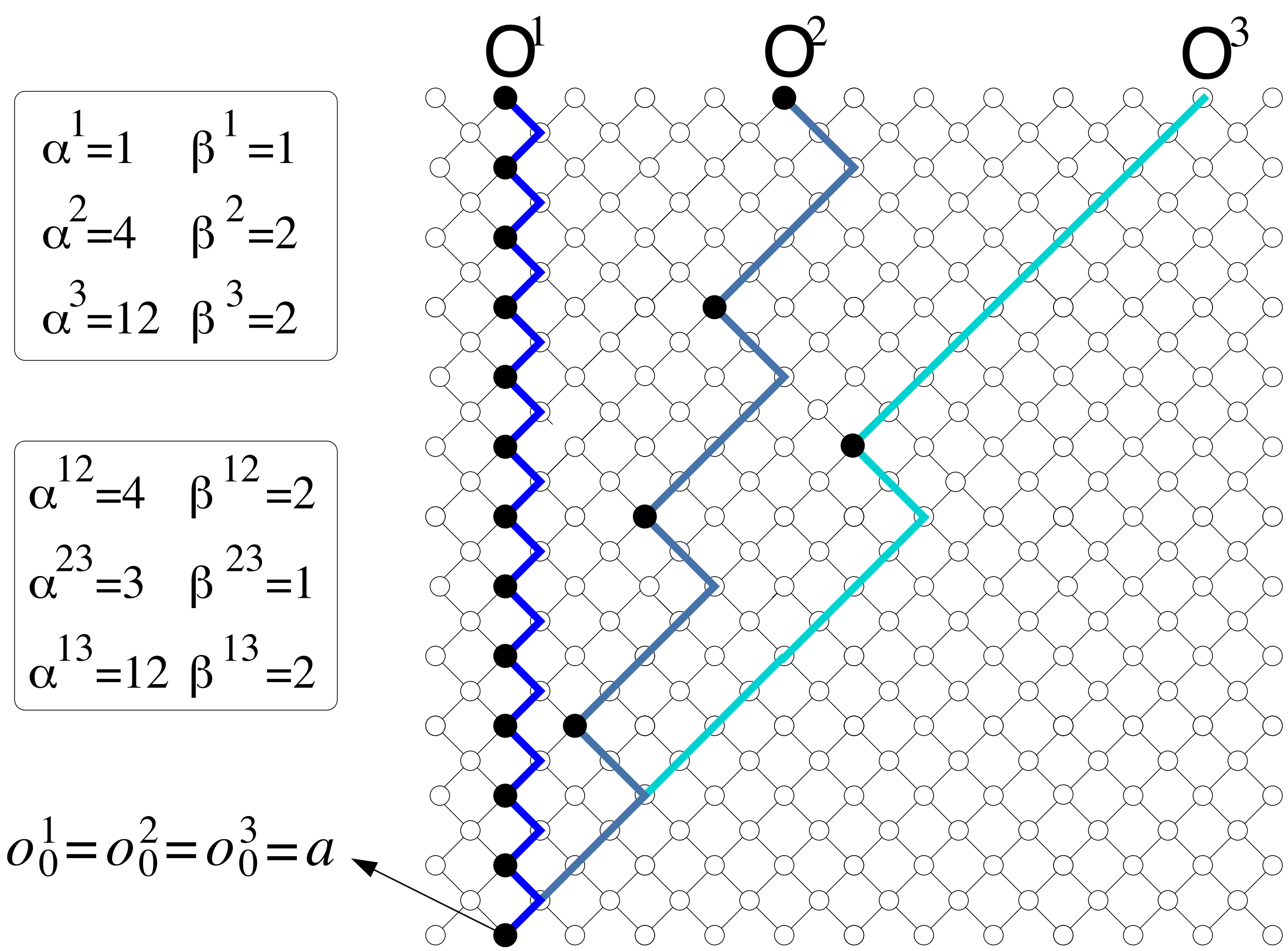
where $\mathbf{U}(\theta)$ is the matrix performing a θ-rotation, can be interpreted as the space-time coordinates of the event b in the frame $\mathsf{L}(\mathsf{O}_a)$.

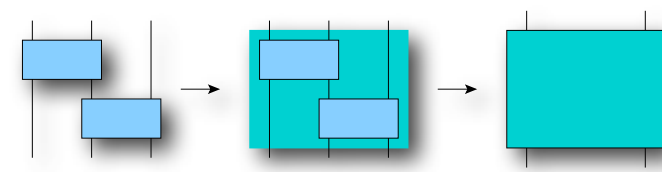
GMD and A. Tosini 1008.4805

Boosts

Frames in standard configuration (boosted). Consider now two observers $\mathsf{O}^1_a = \{o^1_i\}$ and $\mathsf{O}^2_a = \{o^2_j\}$ sharing the same origin (homogeneity guarantees the existence of observers sharing the origin). We will shortly denote the two frames as $\mathfrak{R}^1$ and $\mathfrak{R}^2$, and the corresponding coordinate maps as K^1 and K^2. We will say that the two frames $\mathfrak{R}^1$ and $\mathfrak{R}^2$ are in *standard configuration* if there exist positive α^{12}, β^{12}, such that $\forall i \in \mathbb{Z}$

$$K^1(o^2_i) = \mathbf{D}^{12} K^2(o^2_i), \; \mathbf{D}^{12} := \mathrm{diag}(\alpha^{12}, \beta^{12}). \qquad (11)$$





$$v^{12} = \frac{\alpha^{12} - \beta^{12}}{\alpha^{12} + \beta^{12}}$$

Lorentz transformations from causality and topological homogeneity

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1008.4805

Coordinates

$$v^{13} = \frac{\alpha^{12}\alpha^{23} - \beta^{12}\beta^{23}}{\alpha^{12}\alpha^{23} + \beta^{12}\beta^{23}} = \frac{v_{12} + v_{23}}{1 + v_{12}v_{23}}$$

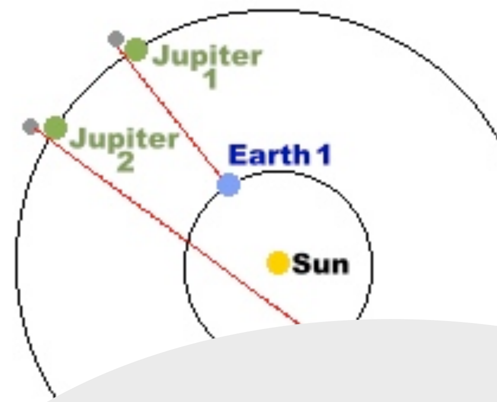
$$t^1 = \chi_{12}\frac{t^2 + v^{12}s^2}{\sqrt{1-(v^{12})^2}}, \qquad s^1 = \chi_{12}\frac{s^2 + v^{12}t^2}{\sqrt{1-(v^{12})^2}},$$

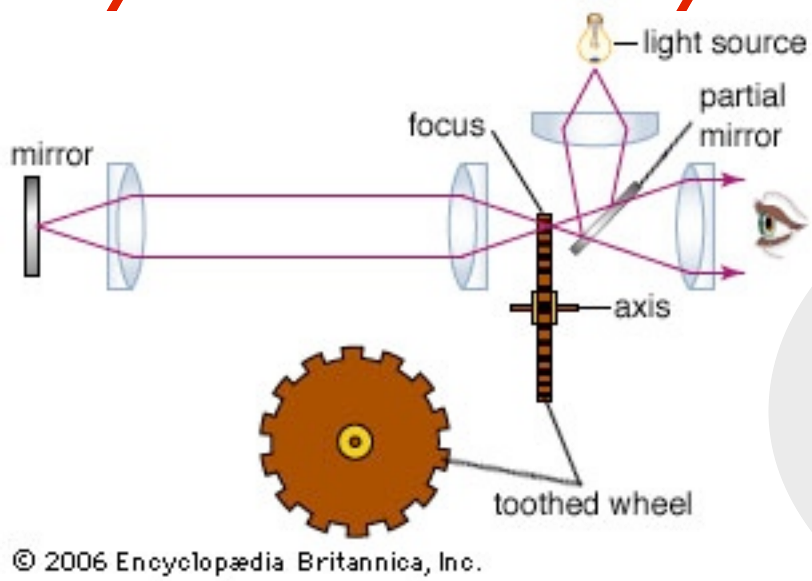
$$\chi_{12} := \sqrt{\alpha^{12}\beta^{12}}$$

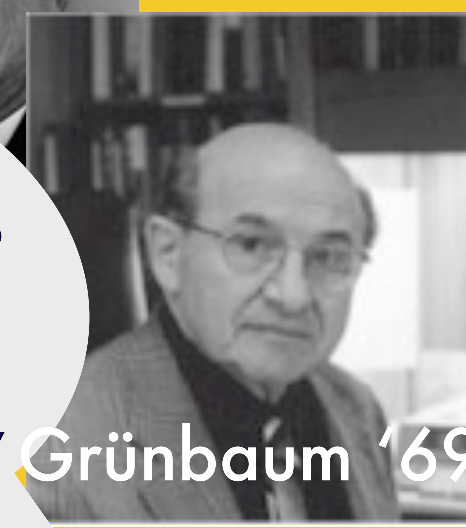
which differ from the Lorentz transformations only by the multiplicative factor χ_{12}. The factor χ_{12} can be removed by rescaling the coordinate map in Eq. (10) using the factor $(2\alpha\beta)^{\frac{1}{2}}$ in place of $2^{\frac{1}{2}}$, with the constants α and β

Conventionality of simultaneity, homogeneity, ...

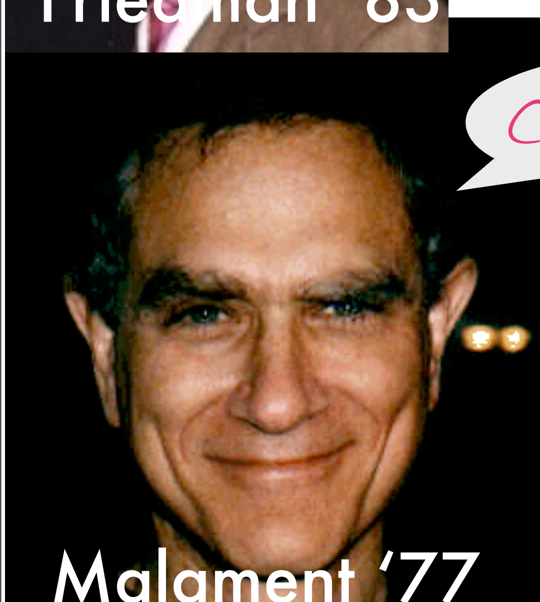
The causal network manifests the *conventionality of simultaneity*.



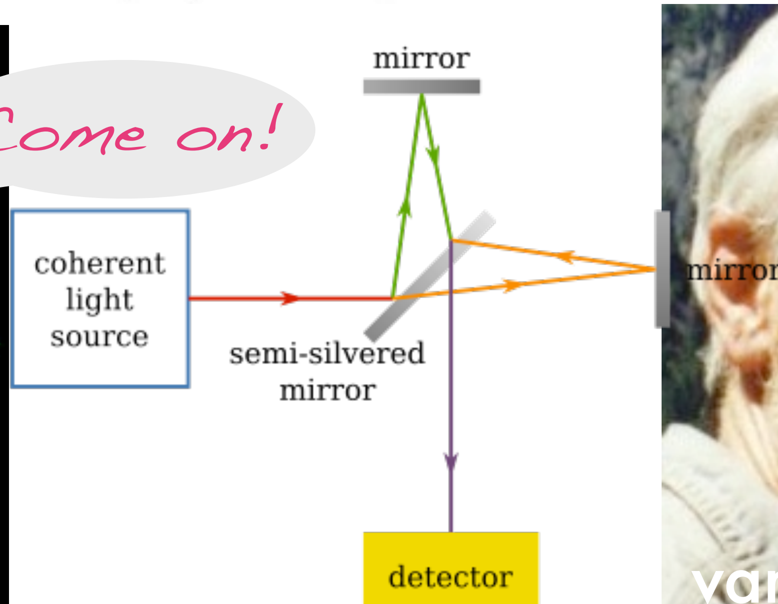




To determine simultaneity of distant events we need to know a speed, to measure a speed we need to know simultaneity of different events ... We can only determine the two-way average speed of light ...



Come on!



WHAT IS THE INFORMATIONAL MEANING OF INERTIAL MASS AND $\hbar$

AND HOW THE QUANTUM FIELD EMERGES

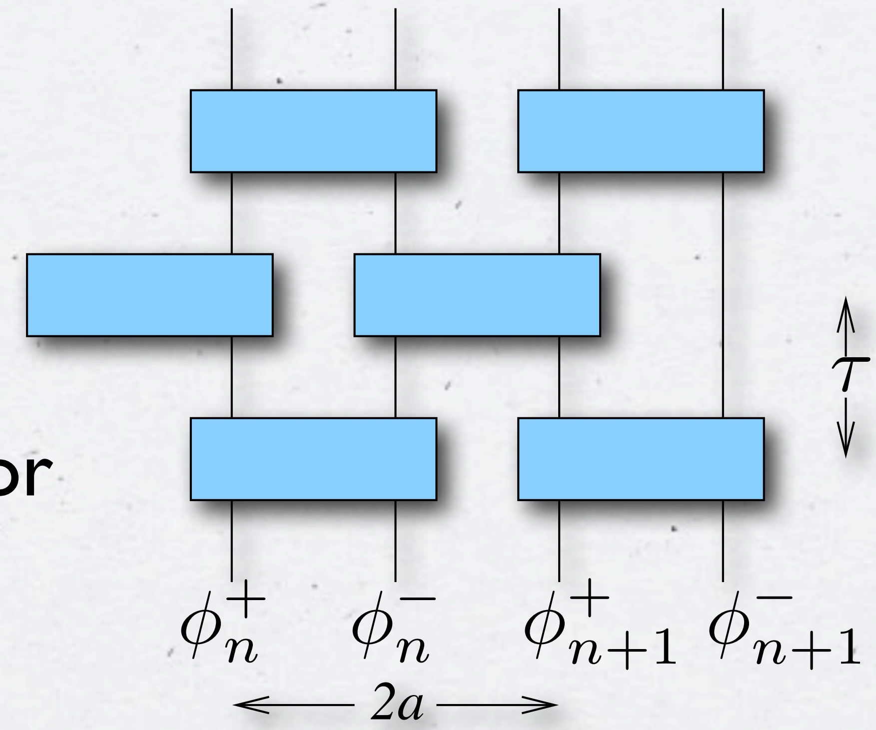
QC SIMULATION OF QFT

SIMPLE SCALAR FIELD IN 1 SPACE DIM.

a: ***topon:*** space-granularity (minimal in principle discrimination between independent events);

τ: ***chronon:*** time-granularity;

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



$\phi^{\pm}_n$ generally nonlocal operators. In QFT they satisfy (anti)commutation relations

Microcausality (equal time)

$$[\phi^{\alpha}_n, \phi^{\beta\,\dagger}_m]_{\pm} = \delta_{\alpha\beta}\delta_{nm}$$

+ : *Fermi*, - : *Bose* (Newton-Wigner)

CAUSAL SPEED

$$v_c := \frac{a}{\tau}$$

QC SIMULATION OF QFT

VIOLATION OF EINSTEIN'S CAUSALITY

★ ★ ★ ★ ★ ★ ★ ★

Simulation of QFT with a quantum computer, with gates performing infinitesimal transformations:

the simulation gives back exactly QFT in the limit $\tau, a \to 0$ and for infinite circuit, but ...

$$v_c = \infty!$$

Galileo!

Einstein causality only in average!

Lorentz-covariance cannot be derived from QT causality!

QC SIMULATION OF QFT

SIMPLE SCALAR FIELD IN 1 SPACE DIM.

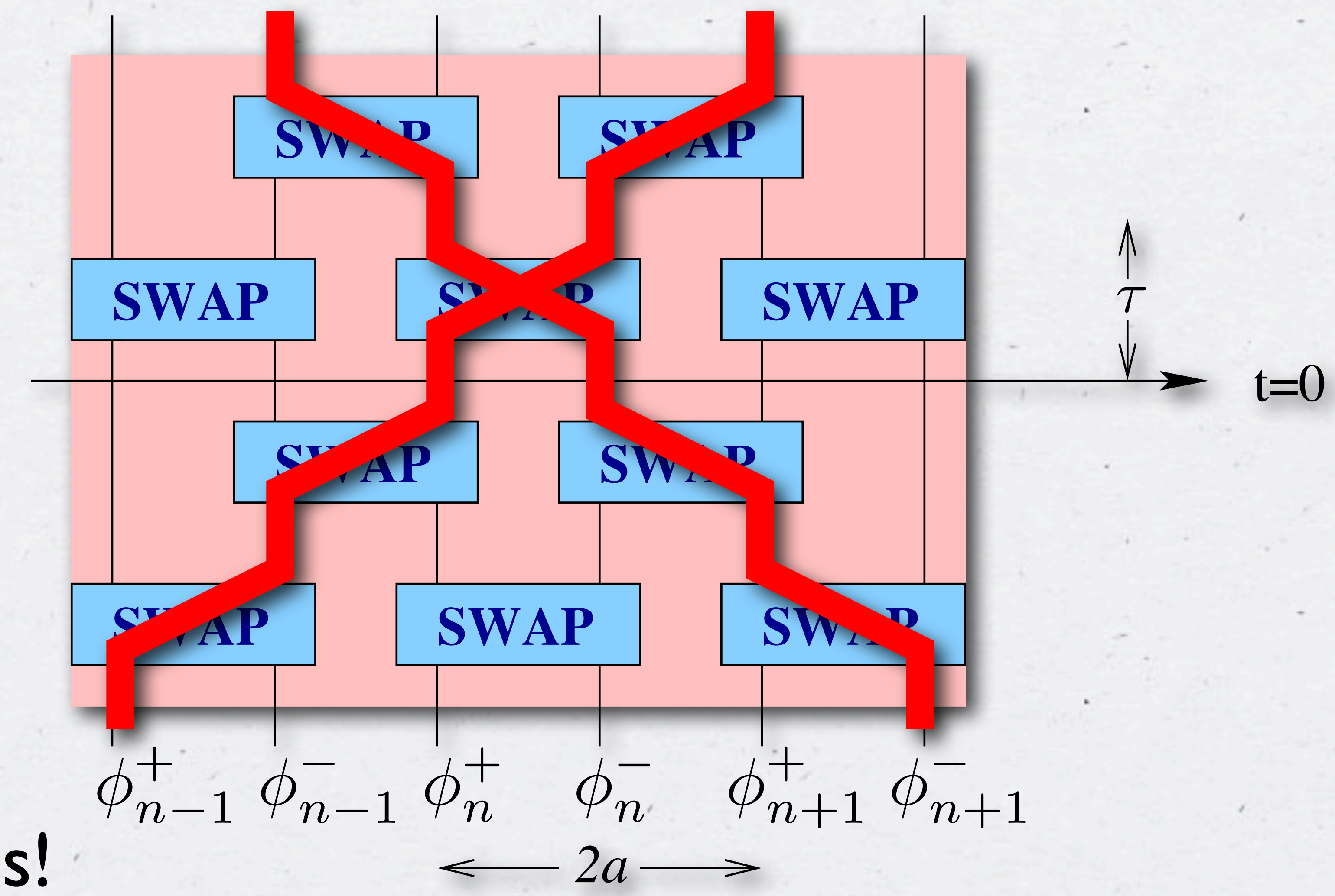
Finite *gate-transformations (not infinitesimal!)*

The causal speed v_c *is finite!*

Lorentz's transformations emerge from the causal network

Different QFT

observational consequences!



QC SIMULATION OF QFT

SIMPLE SCALAR FIELD IN 1 SPACE DIM.

$$U z_n U^\dagger = \sum_k \mathbf{U}_{nk} z_k$$

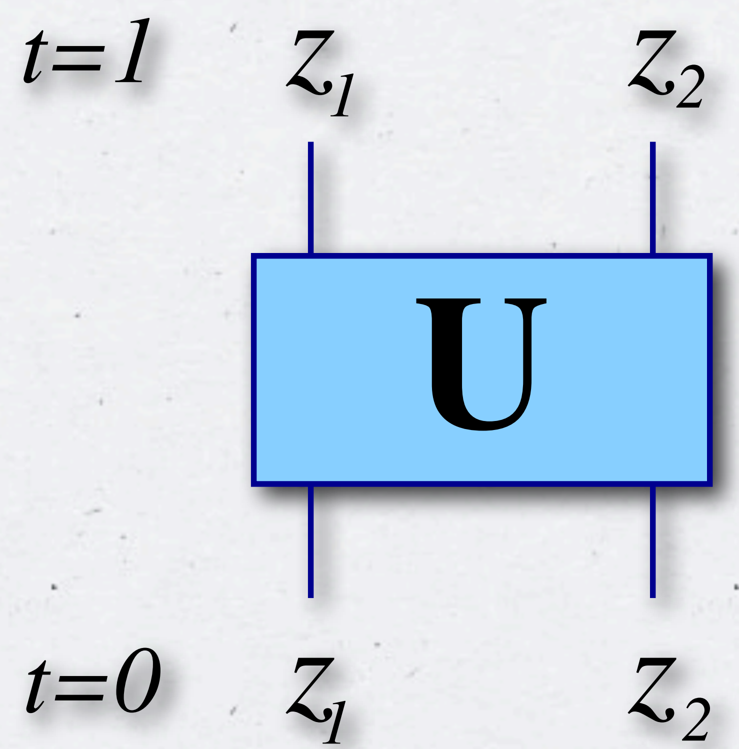
$\mathbf{U} = \|\mathbf{U}_{ij}\|$ unitary matrix

Each gate evolves the field *linearly:*

$$[z_i, z_j^\dagger]_\pm = \delta_{ij}$$

Evolution from bipartite gates:

$$\begin{bmatrix} z_1 \\ z_2 \end{bmatrix}_{t=1} = U \begin{bmatrix} z_1 \\ z_2 \end{bmatrix} U^\dagger = \mathbf{U} \begin{bmatrix} z_1 \\ z_2 \end{bmatrix}$$



QC SIMULATION OF QFT

SIMPLE SCALAR FIELD IN 1 SPACE DIM.

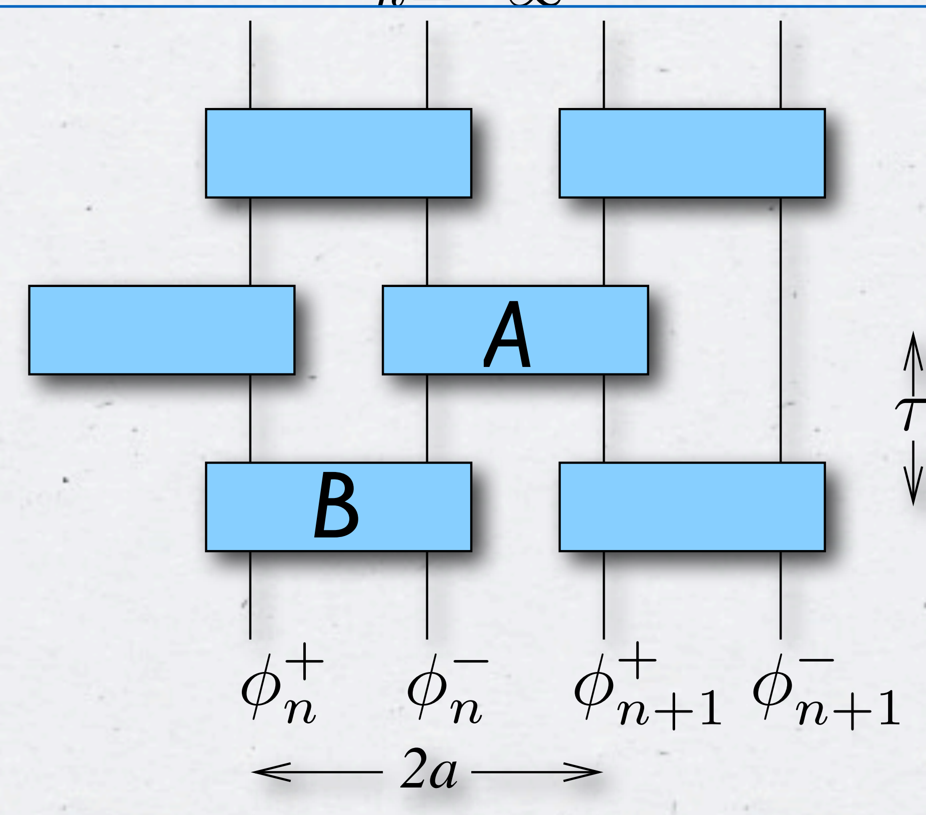
Commuting	Anticommuting
Field is a local operator	*Clifford algebraic construction*
gates act on local algebras	$\phi_n^+ = \sigma_{2n}^- \prod_{k=-\infty}^{n-1} \sigma_{2k+1}^z \sigma_{2k}^z$
	$\phi_n^- = \sigma_{2n+1}^- \sigma_{2n}^z \prod_{k=-\infty}^{n-1} \sigma_{2k+1}^z \sigma_{2k}^z$

According to Jordan-Schwinger:

$$A = A(\vec{\sigma}_{2n+1}, \vec{\sigma}_{2n+2})$$

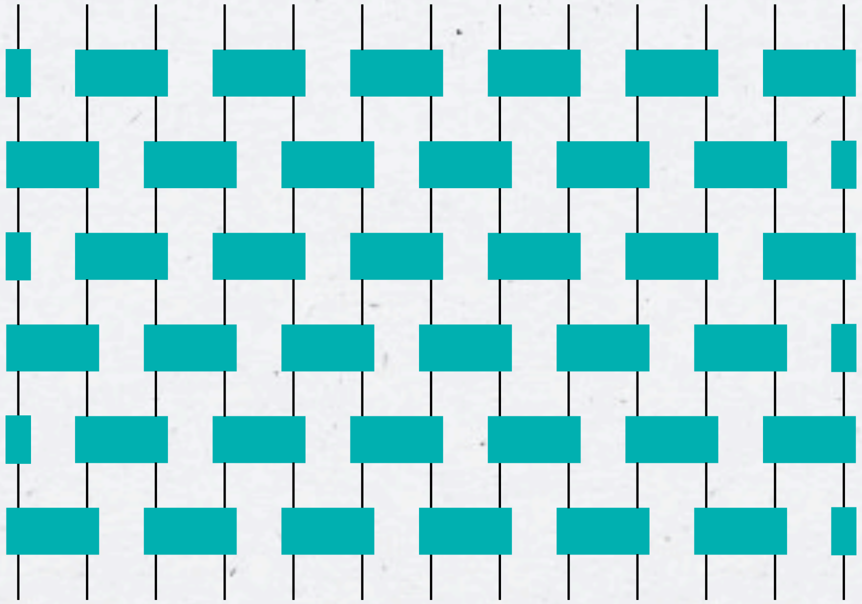
$$B = B(\vec{\sigma}_{2n}, \vec{\sigma}_{2n+1})$$

i.e. gates act on local algebras also for anticommuting fields



THE NEW QCFT

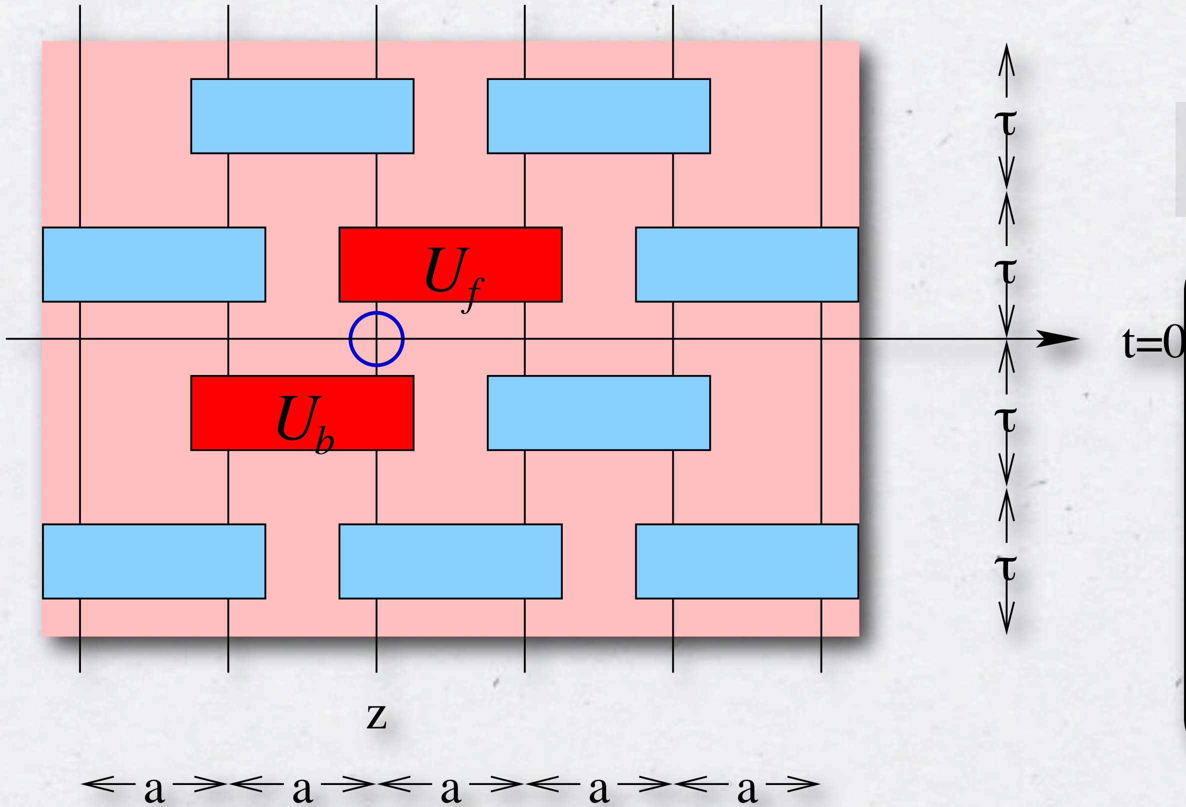
SIMPLE SCALAR FIELD IN 1 SPACE DIM.



Coarse-grained discrete derivatives:

$$\widehat{\partial}_t z = \frac{1}{2k\tau}[z(k\tau) - z(-k\tau)]$$

$$\widehat{\partial}_x = \frac{1}{4ka}(\delta_+^k - \delta_-^k)$$



"HAMILTONIAN"

$$\mathrm{H}_{\mathrm{gate}}^{(2\mathrm{n})} z = \frac{i}{2n\tau}[z(n\tau) - z(-n\tau)] = i\widehat{\partial}_t z$$

$$\mathrm{H}_{\mathrm{gate}}^{(2)} z = \frac{i}{2\tau}(U_f z U_f^\dagger - U_b^\dagger z U_b)$$

THE NEW QCFT

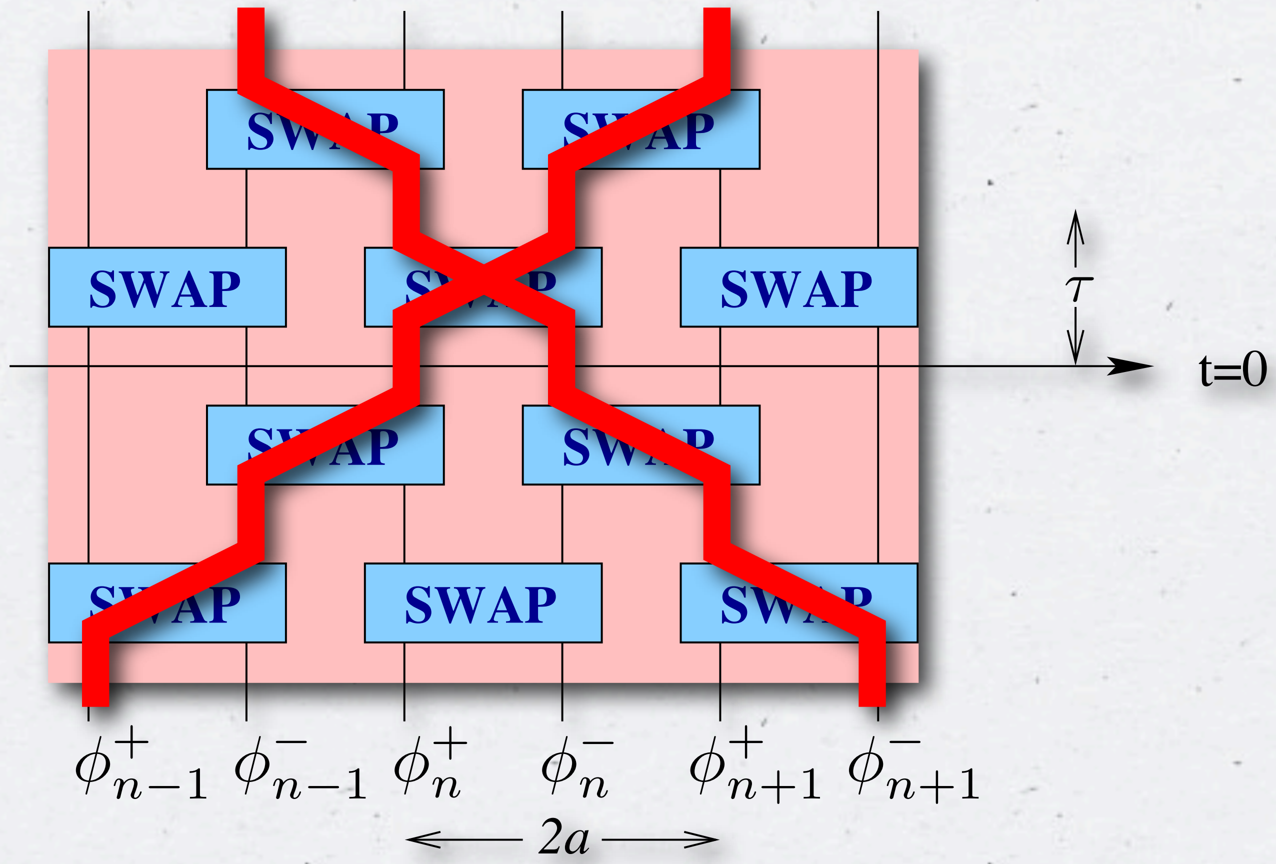
MASSLESS FIELD

★ ★ ★ ★ ★ ★ ★ ★

NEW QFT: *finite gate-transformations (not infinitesimal!)*

$$\phi_n^+(\pm 2\tau) = \phi_{n\pm 1}^+(0), \quad \phi_n^-(\pm 2\tau) = \phi_{n\mp 1}^-(0)$$

$$\mathrm{H}_{\mathrm{gate}}^{(4)} \phi_n^\alpha = i\alpha v_c \widehat{\partial}_x \phi_n^\alpha, \ \alpha = \pm$$



$$\mathrm{H}_{\mathrm{gate}}^{(4)} \boldsymbol{\phi}_n = i\sigma_z v_c \widehat{\partial}_x \boldsymbol{\phi}_n$$

$$\widehat{\Box} \boldsymbol{\phi}_n = 0$$

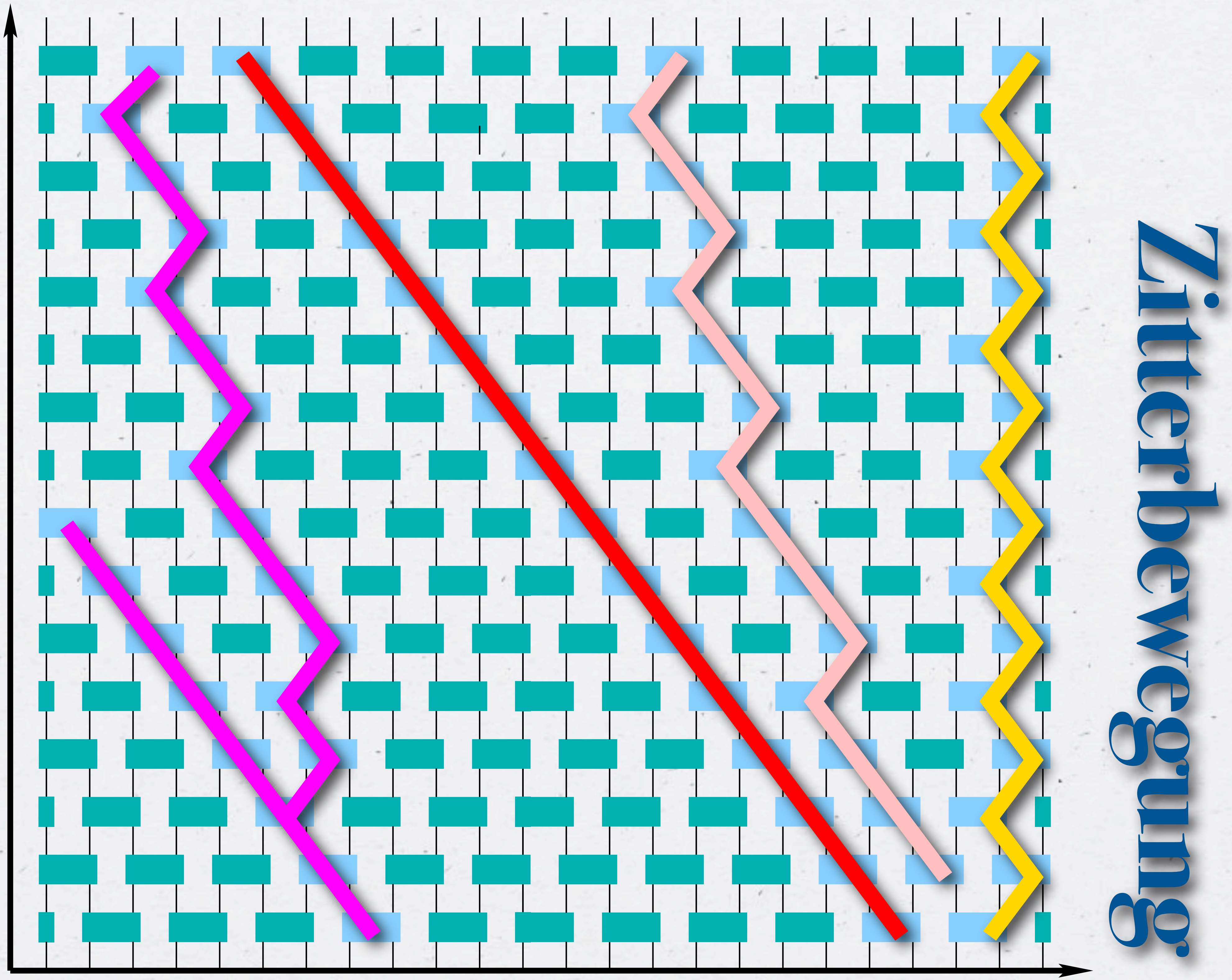
$$\widehat{\Box} = \widehat{\partial}_x^2 - \frac{1}{v_c^2}\widehat{\partial}_t^2$$

mercoledì 20 ottobre 2010

OBSERVATIONAL CONSEQUENCES: MASS-DEPENDENT REFRACTION INDEX OF VACUUM

THE NEW QCFT

WHAT IS INERTIAL MASS?



THE NEW QCFT

WHAT IS $\hbar$?

$$m = \frac{\tau^2}{a^2}\hbar\nu$$

$$i\widehat{\partial}_t \begin{bmatrix}\phi^+ \\ \phi^-\end{bmatrix} = \begin{bmatrix} iv\widehat{\partial}_x & \nu \\ \nu & -iv\widehat{\partial}_x \end{bmatrix} \begin{bmatrix}\phi^+ \\ \phi^-\end{bmatrix}$$

m	*mass in grams*
a	*topon*
τ	*chronon*
ν	*coupling between ± modes*
$\lambda = \frac{\hbar}{mc}$	*Compton wavelenght*

THE NEW QCFT

MASS-DEPENDENT VACUUM REFRACTION INDEX

★ ★ ★ ★ ★ ★ ★ ★

Overall we must have: $U_f \phi_n^+ U_f - U_b^\dagger \phi_n^+ U_b = \zeta(\phi_{n+1}^+ - \phi_{n-1}^+) - 4i\frac{a}{\lambda}\phi_n^-$

For local gates involving only n.n. wires, the overall forward and backward unitary interactions involving a minimal number of field operators have the form

$$U_f \phi_n^+ U_f^\dagger = \eta\phi_n^+ + \zeta\phi_{n+1}^+ + \gamma\phi_n^- \qquad U_b^\dagger \phi_n^+ U_b = \eta\phi_n^+ + \zeta\phi_{n-1}^+ + \gamma'\phi_n^-$$

with $\zeta > 0$ and $\gamma - \gamma' = -4i\frac{a}{\lambda}$

But normalization of the row of the unitary matrix corresponds to:

$$|\gamma|, |\gamma'| \leqslant \sqrt{1-\zeta^2} \implies \frac{2a}{\lambda} \leqslant \sqrt{1-\zeta^2}$$

which is the bound for the vacuum refraction index:

$$\zeta^{-1} \geqslant \left[1 - \left(\frac{2a}{\lambda}\right)^2\right]^{-\frac{1}{2}}$$

Effect visible at large mass $\lambda \sim 2a$

THE NEW QCFT

FEYNMAN PATH-SUM

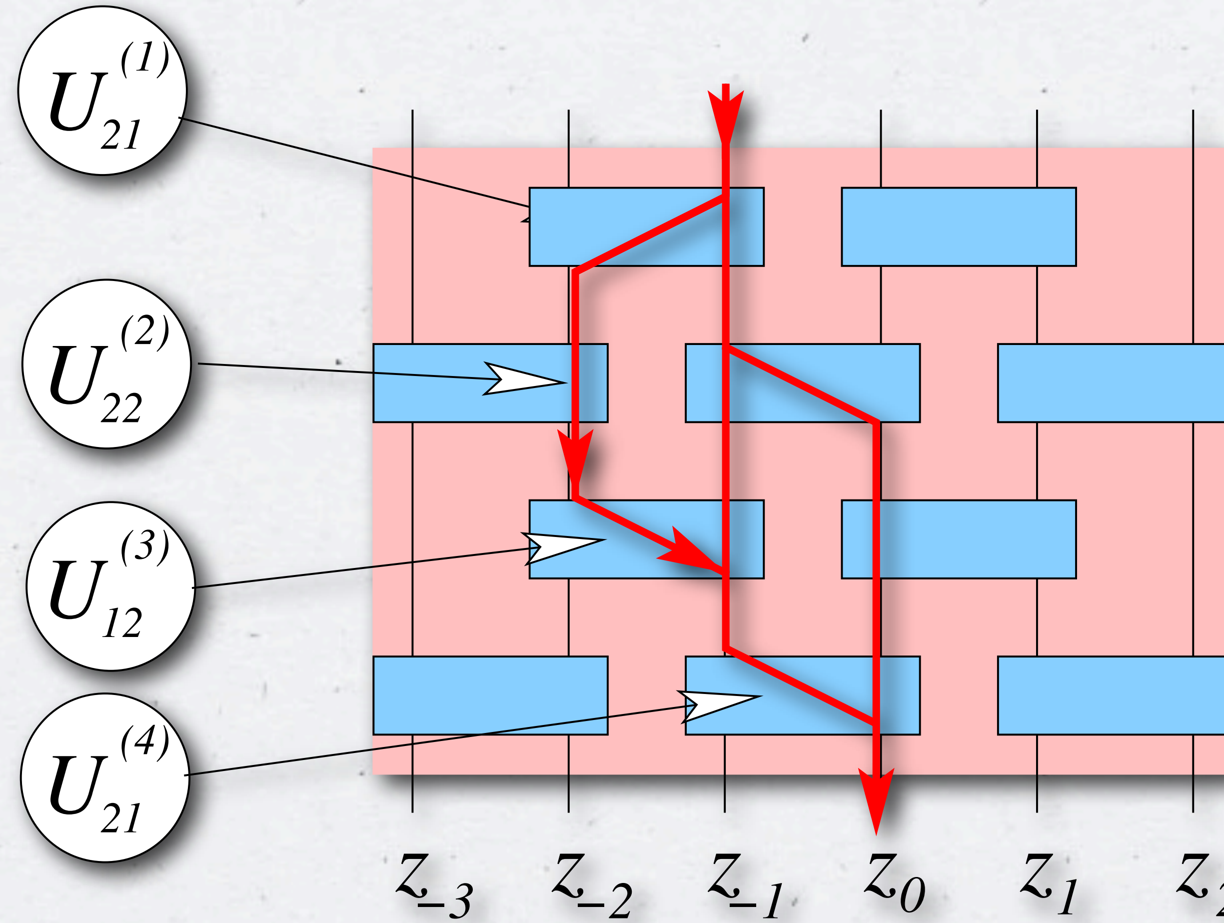
We need to develop a *path-sum calculus* over the circuit:

1. Number all the input wires at each gate, from the leftmost to the rightmost one, and do the same for the output wires

2. We say that a wire l is in the past-cone of the wire k if there is a path from *l* to k passing through gates.

3. For any output wire k and any input wire l in its causal past cone, consider all paths connecting k with l

4. The following linear expansion holds



$$z_l(t) = \sum_{\mathbf{i}_{kl}} U^{(1)}_{i_1 i_2} U^{(2)}_{i_2 i_3} \ldots U^{(n)}_{i_n i_{n+1}} z_k(0)$$

$\mathbf{i}_{kl} = (i_1 i_2 \ldots i_n i_{n+1})$ with $i_1 = k,\ i_{n+1} = l,$

THE NEW QCFT

KLEIN GORDON WITH MASS

★ ★ ★ ★ ★ ★ ★ ★

"Hamiltonian"

$$\mathrm{H}^{(4)}_{\mathrm{gate}} = \frac{i}{4\tau}\begin{bmatrix} A_{21}B_{21}\delta_- - B^\dagger_{12}A^\dagger_{12}\delta_+ + A_{22}B_{11} - B^\dagger_{11}A^\dagger_{22} & (A_{21}B_{22} - B^\dagger_{11}A^\dagger_{21})\delta_- + A_{22}B_{12} - B^\dagger_{12}A^\dagger_{11} \\ (A_{12}B_{11} - B^\dagger_{22}A^\dagger_{12})\delta_+ + A_{11}B_{21} - B^\dagger_{21}A^\dagger_{22} & A_{12}B_{12}\delta_+ - B^\dagger_{21}A^\dagger_{21}\delta_- + A_{11}B_{22} - B^\dagger_{22}A^\dagger_{11} \end{bmatrix}$$

Hermiticity is satisfied:

$$\langle\phi_n^\pm|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_n^\pm\rangle = \langle\phi_n^\pm|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_n^\pm\rangle^* \Longrightarrow i(A_{aa}B_{bb} - A^\dagger_{aa}B^\dagger_{bb}) \in \mathbb{R},$$

$$\langle\phi_n^\pm|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_n^\mp\rangle = \langle\phi_n^\mp|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_n^\pm\rangle^* \Longrightarrow (A_{22}B_{12} - A^\dagger_{11}B^\dagger_{12}) = -(A_{11}B_{21} - A^\dagger_{22}B^\dagger_{21})^*,$$

$$\langle\phi_{n+1}^\pm|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_n^\pm\rangle = \langle\phi_n^\pm|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_{n+1}^\pm\rangle^* \Longrightarrow A^\dagger_{ab}B^\dagger_{ab} = A^*_{ba}B^*_{ba},$$

$$\langle\phi_n^+|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_{n-1}^-\rangle = \langle\phi_n^-|\mathrm{H}^{(4)}_{\mathrm{gate}}|\phi_{n+1}^+\rangle^* \Longrightarrow A_{21}B_{22} - A^\dagger_{21}B^\dagger_{11} = -(A_{12}B_{11} - A^\dagger_{12}B^\dagger_{22})^*.$$

THE NEW QCFT

KLEIN GORDON WITH MASS

★ ★ ★ ★ ★ ★ ★ ★

Using the smoothness constraint $\frac{1}{2}(\delta_+ + \delta_-) \simeq 1$ corresponding to $\delta_\pm = 1 \pm 2a\widehat{\partial}_x$ one writes the Hamiltonian in the Dirac fashion:

$$\mathrm{H}^{(4)}_{\mathrm{gate}} = v_c(\mathbf{H} + \mathbf{K}\widehat{\partial}_x), \quad \mathbf{H} := \begin{bmatrix} H_{11} & H_{12} \\ H^*_{12} & H_{22} \end{bmatrix}, \ \mathbf{K} := \begin{bmatrix} K_{11} & K_{12} \\ -K^*_{12} & K_{22} \end{bmatrix},$$

Restrict to KG with propagation speed ζc, namely

$$(\mathrm{H}^{(4)}_{\mathrm{gate}})^2 = -c^2(\zeta^2\widehat{\partial}^2_x - \lambda^{-2})$$

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

Compton wavelength

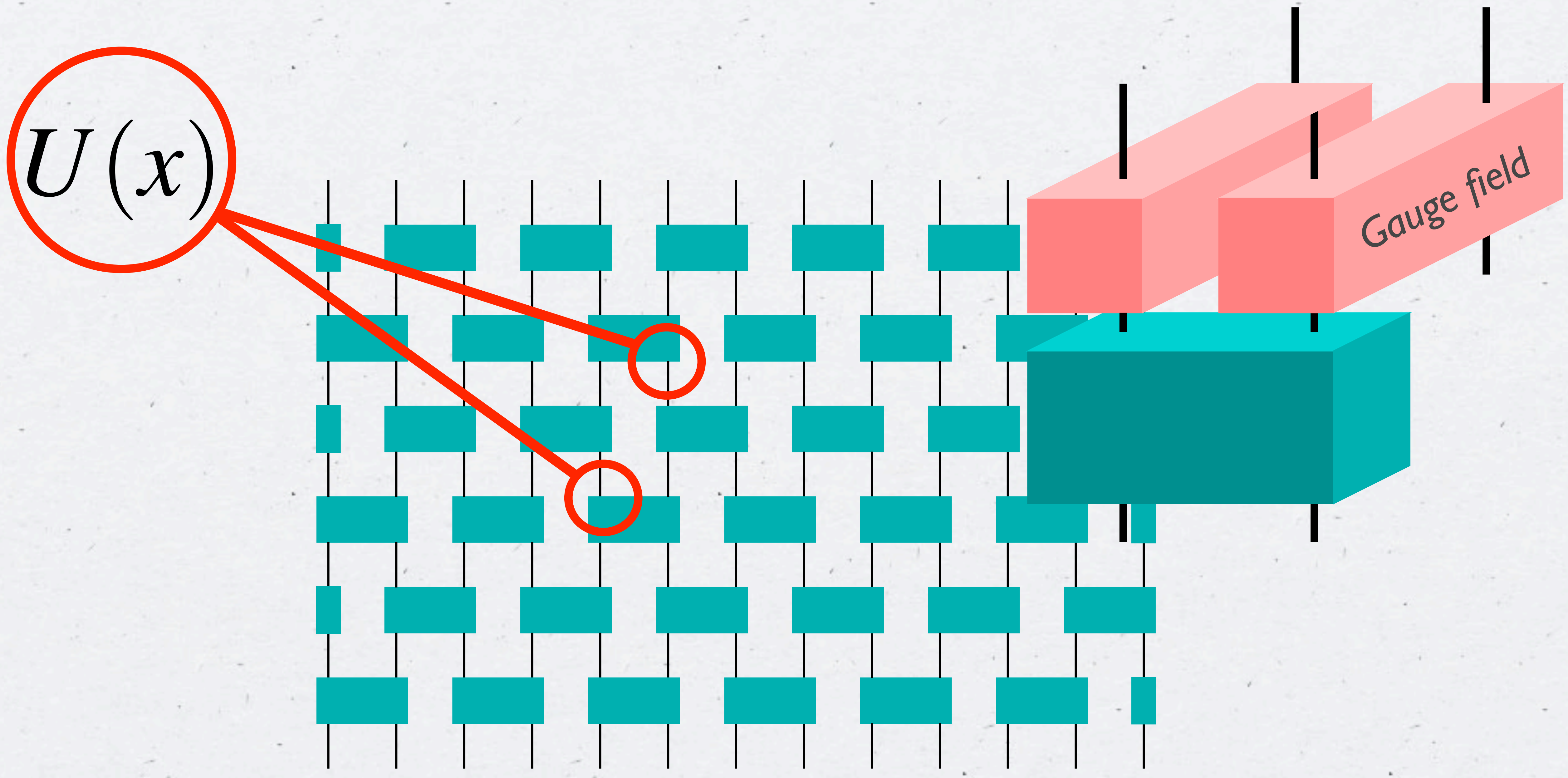
After some manipulations one gets the mass-dependent vacuum refraction index:

$$\zeta^{-1} = \frac{2}{1 + \sqrt{1 - \left(\frac{2a}{\lambda}\right)^2}}$$

Easy to generalize to particles with spin

THE NEW QCFT

GAUGE INVARIANCE



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

→ ***Good for QGravity?***

THE NEW QCFT

QCFT FOR MORE THAN 1 SPACE DIM?

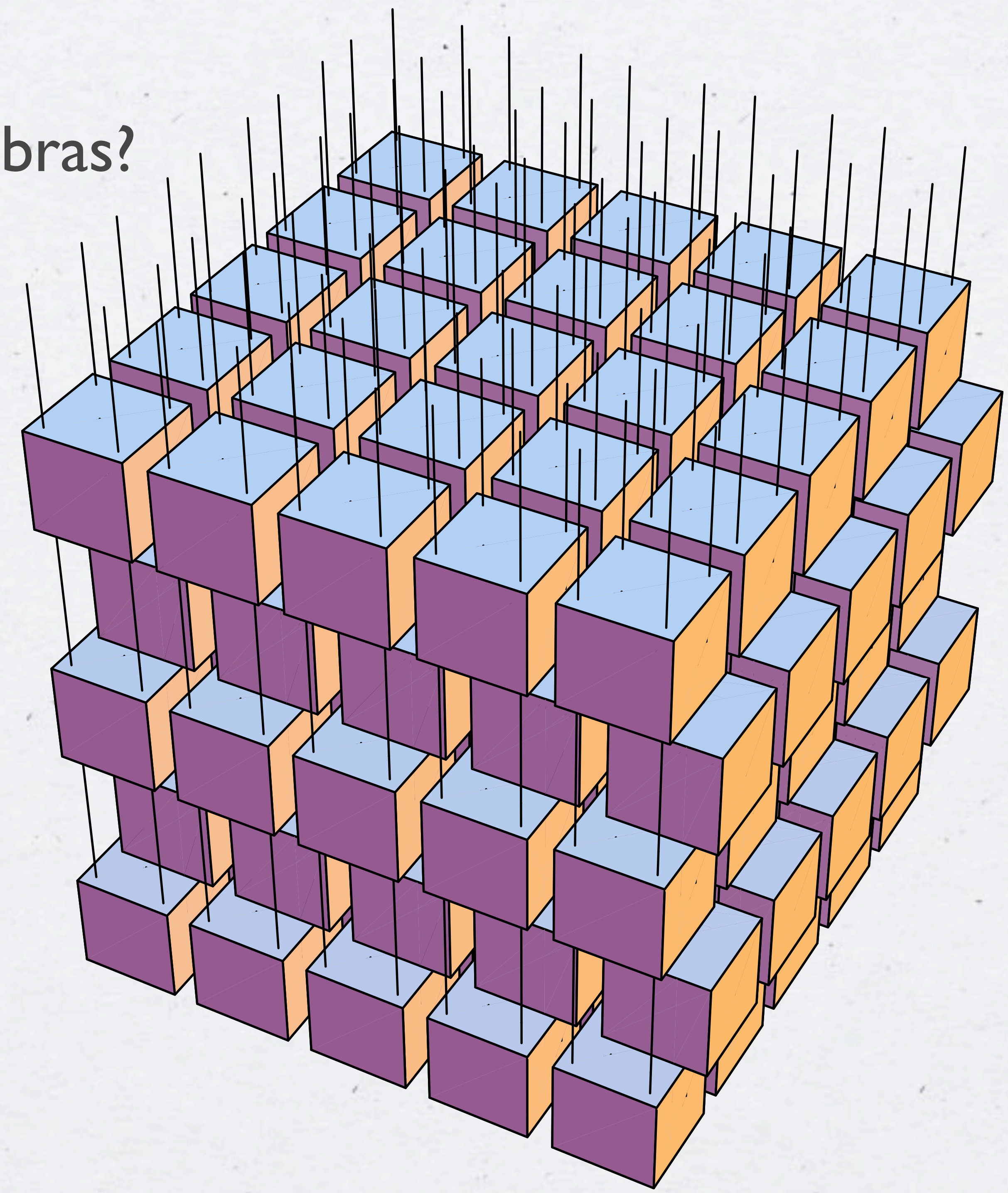
Need six space field operators

Anticommuting fields in terms of local algebras?

Do we really need anticommuting fields?

Grassman variables?

Microcausality and parastatistics



THE NEW QCFT

COMPARED TO THE USUAL QFT

QCFT solve many problems that plague QFT:

* Feynman’s path integral
* u.v. renormalization
* no need of quantization rules (must be emergent)
* problems related to the continuous
* ...

The idea is to regard the QCFT as the “true theory”, and the usual QFT as an approximation for “mesoscopic” scale

CONCLUSIONS

PHYSICS IS INFORMATION

- Quantum Theory is an information theory
- Space-time and relativistic covariance emerge from the information processing
- The whole Physics is emergent (inertial mass, Planck constant, quantization rules, ...)
- The new causal QCFT:
  - has no space-background (QG-ready)
  - doesn't need quantization
  - cures many problems that plague QFT
  - opens a new route to foundations of QFT
  - has empirical consequences ...

TODO SOON

PHYSICS IS INFORMATION

- Quantization rules as emergent
- General correspondence: Lagrangian-gates
- Anticommuting fields and (parastatistics)
- Emergent unitary representation of the Lorentz group
- Violations of Lorentz-covariance
- Informational meaning of energy, gravitational mass,...
- Build up a complete QCFT for Dirac in 3 space dimensions
- Experimental consequences ...

THANK YOU