

Title: Quantum Information and holography

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Collection: Quantum Information and holography (2021/2022)

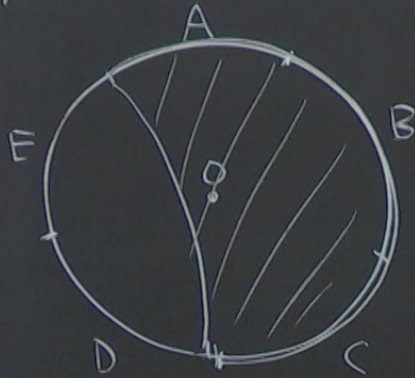
Date: May 04, 2022 - 9:00 AM

URL: <https://pirsa.org/22050005>

Abstract: Topics will include (but are not limited to):

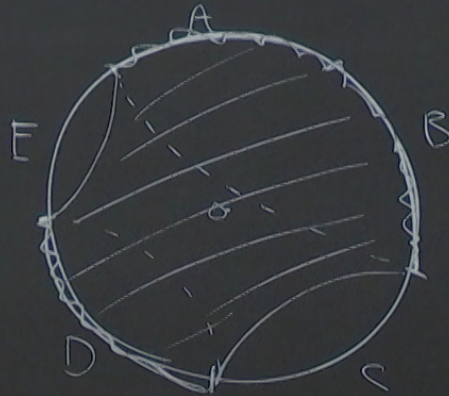
- Quantum error correction in quantum gravity and condensed matter
- Quantum information scrambling and black hole information
- Physics of random tensor networks and random unitary circuits

Toy model



ABC
Causal wedge.

$\mathcal{O}_{ABC}$

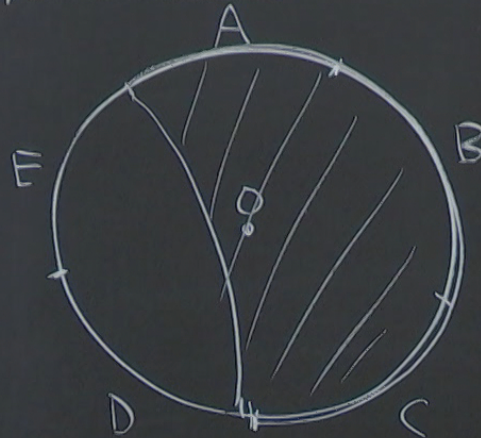


ABD
Entangled wedge.

$\mathcal{O}_{ABD}$

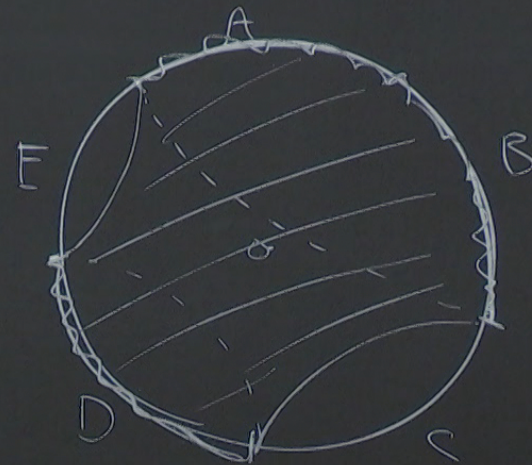
$\mathcal{O}$ ABC, BCD, CDE, ...
ABD, BCE, ...

Toy model



ABC
Causal wedge.

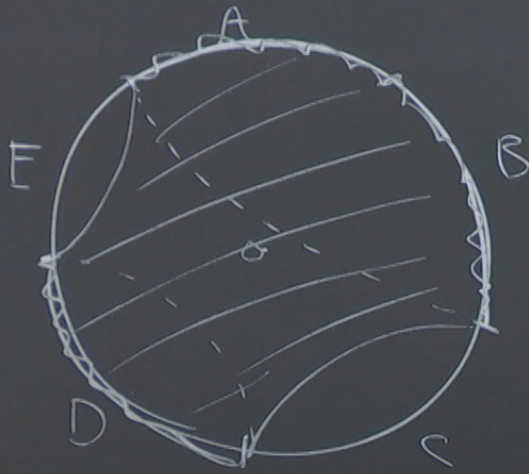
$\mathcal{O}_{ABC}$



ABD
Entangled wedge.

$\mathcal{O}_{ABD}$

$\mathcal{O}$ AB
AB
 $\nabla \mathcal{O}$ or



ABD
Entangled w/ C

$\odot_{ABD}$

$\emptyset$ ABC, BCD, CDE, ...
ABD, BCE, ...

$\neq \emptyset$ on any subsystem of 3.

5 qubit code

$$1 \rightarrow 5$$

$$\begin{array}{cc} 2\text{-dim} & 32\text{-dim} \\ \mathcal{H}_{\text{code}} & \subseteq \mathcal{H} \end{array}$$

$$|4\rangle = c_0|0\rangle + c_1|1\rangle \quad 1 \text{ qubit}$$

$$|\Phi\rangle = c_0|\Phi\rangle + c_1|\Psi\rangle \quad 5 \text{ qubits}$$

Stabilizer formalism

$$S_1 = X \quad Z \quad Z \quad X \quad I$$

$$S_2 = I \quad X \quad Z \quad Z \quad X$$

$$S_3 = Z \quad I \quad X \quad Z \quad Z$$

$$S_4 = Z \quad X \quad I \quad X \quad Z$$

$$(S_5 = Z \quad Z \quad X \quad I \quad X)$$

$$\begin{array}{l}
 I \quad S_j^2 = I \quad S_j = \pm 1 \text{ eigenvalues.} \quad \text{H.cde.} \quad (S_j |\tilde{\psi}\rangle = +|\tilde{\psi}\rangle \\
 \times \quad [S_i, S_j] = 0. \\
 \approx \quad S_1 S_2 \cdots S_5 = I \\
 \times \approx \\
 \times)
 \end{array}$$

values.

code.

$$S_3 |\tilde{\psi}\rangle = +|\tilde{\psi}\rangle$$

S_1, S_2, S_3, S_4

$\pm 1 \quad \pm 1 \quad \pm 1 \quad \pm 1$

$$\tilde{X} = X X X X X$$

$$\tilde{Z} = Z Z Z Z Z$$

$$[\tilde{X}, S_j] = 0.$$

$$[\tilde{Z}, S_j] = 0.$$

$$\tilde{Z} |0\rangle = |0\rangle$$

$$\tilde{Z} |\uparrow\rangle = -|\uparrow\rangle$$

$$\{\tilde{X}, \tilde{Z}\} = 0$$

$$\tilde{X} = |0\rangle\langle\uparrow| + |\uparrow\rangle\langle 0|$$

1
X,
Z

encode

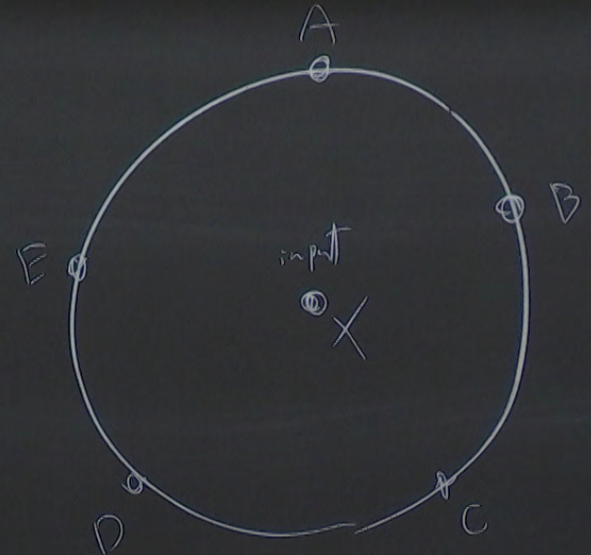
S.
 $\tilde{X}$
 $\tilde{Z}$.

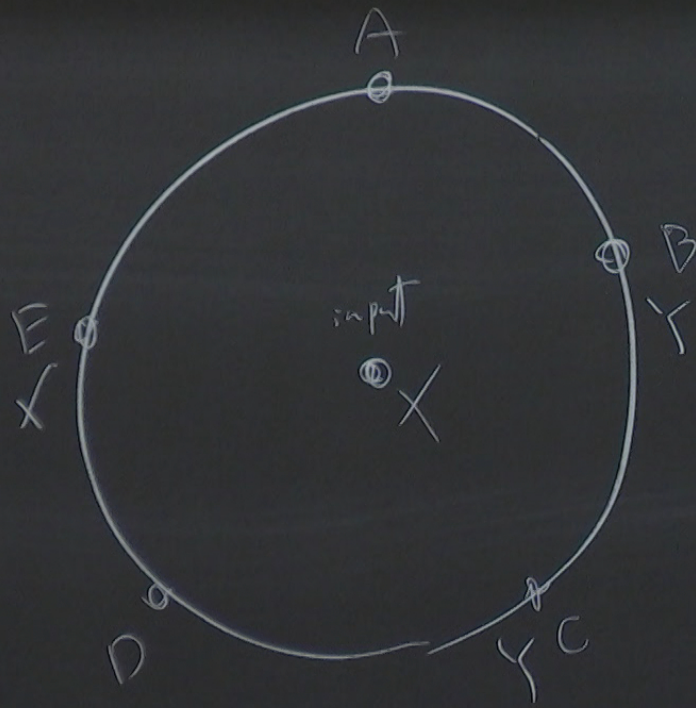
$\hat{O}_{\text{bulk}}$

logi-2 operator.
boundary op.

$$\hat{X}_{S_1} = -I Y Y I X \equiv \hat{X}_{BCE}$$

$$\hat{X}_{S_1 S_2} = I Z X Z I \equiv \hat{X}_{BCD}$$



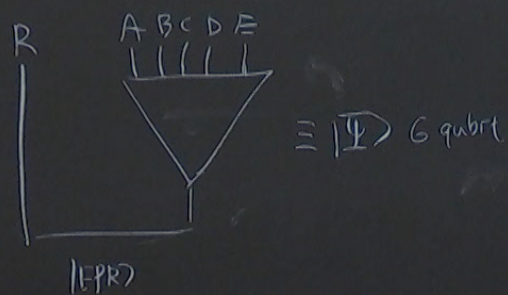
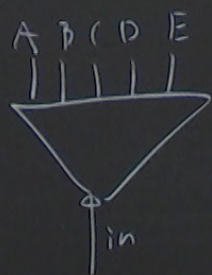


Reversible fm 3
Subsystems



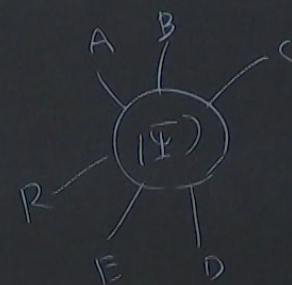
Protected from erasure
of 2 subsystems

Perfect code / tensor



$|\Psi\rangle$ is "perfect"

$$\begin{aligned} S_A &= 1 \\ S_{AB} &= 2 \\ S_{ABC} &= 3 \\ S_{ABCD} &= 2 \end{aligned}$$



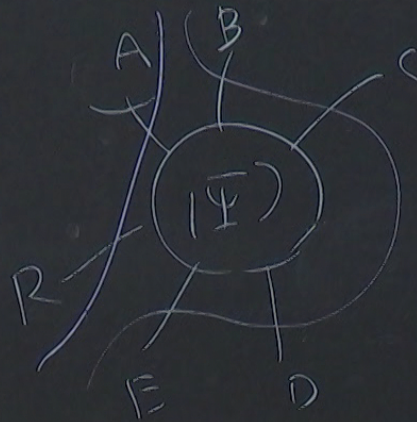
$\overline{14}$ is "perfect" satisfying RT formulae

$$S_A = 1$$

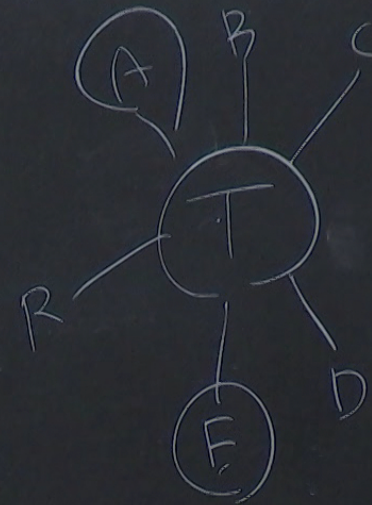
$$S_{AB} = 2$$

$$S_{ABC} = 3$$

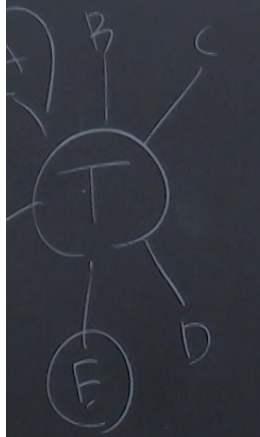
$$S_{ABCD} = 2$$



$$S_{AR} = 2$$

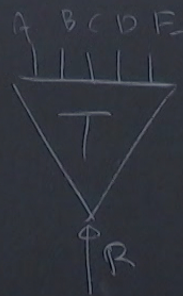


$$S_{AE} = 2$$



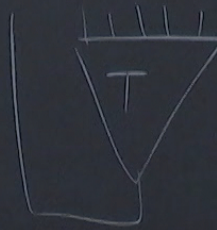
$$SAE = 2$$

$$1 \rightarrow 5$$



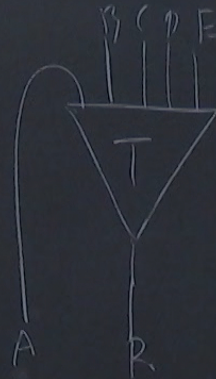
code

$$0 \rightarrow 6$$



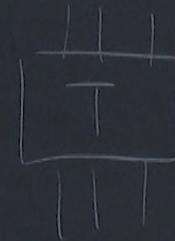
state

$$2 \rightarrow 4$$



code

$$3 \rightarrow 3$$



unitary

