Gong Show

The preview session by the poster presenters today

#1

#2

#3

#4

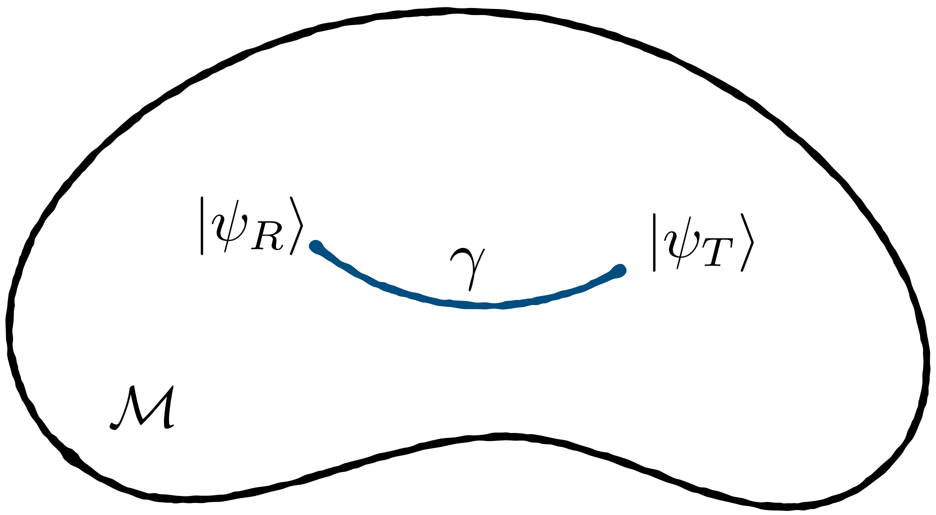
Circuit Complexity & 2D Bosonisation

1904.03003 with G. Policastro

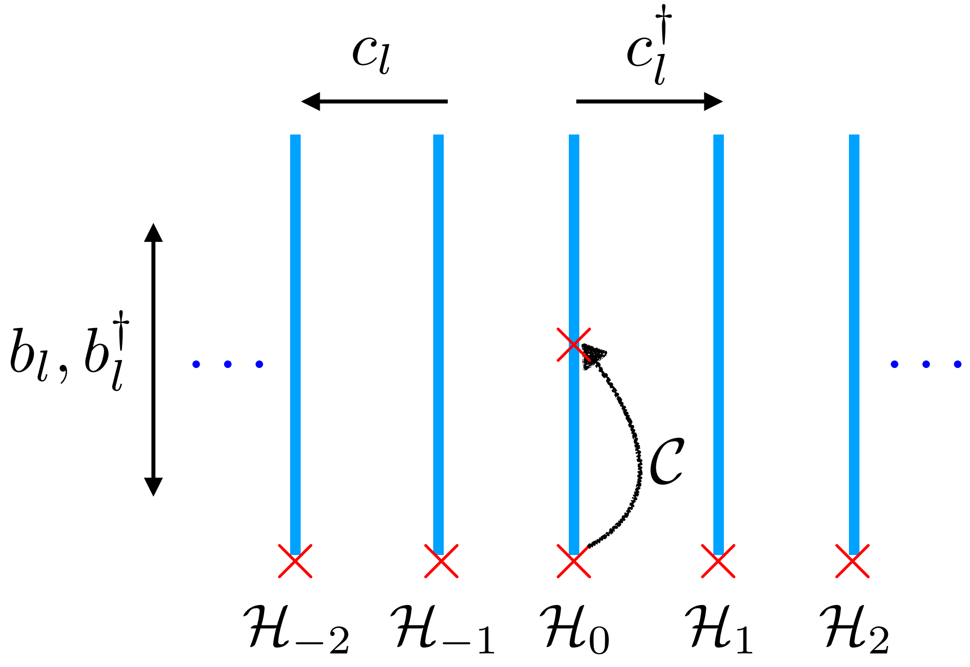
Dongsheng Ge
LPENS

ENS

Département de Physique
École normale supérieure



$$\mathcal{C}(|\psi_R\rangle, |\psi_T\rangle) = \min ||\gamma||$$



- Bosonic states are simultaneously fermionic states, different form of gates
- Bosonic Coherent states & fermionic Gaussian states
- Bosonic Gaussian states & fermionic Gaussian states

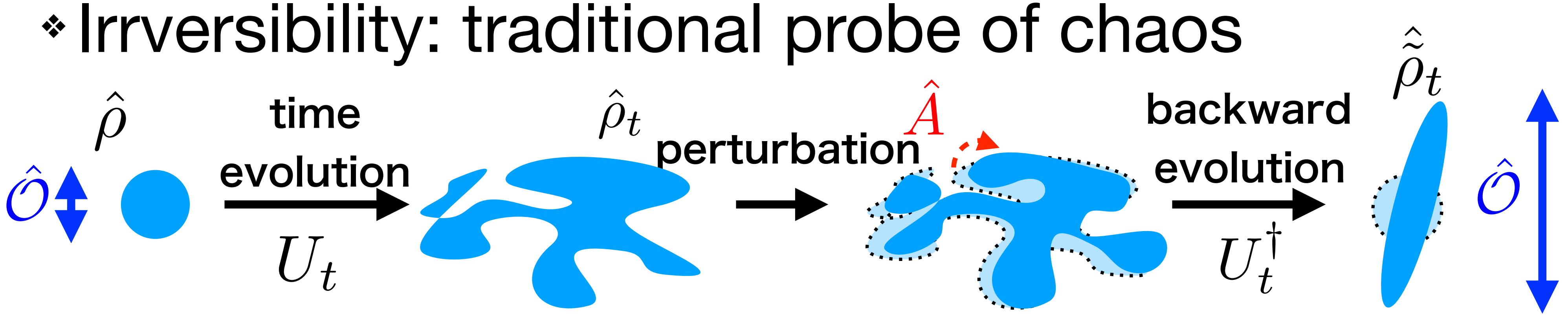
More detailed story, come to Y206 #4!!!

#5

Operator noncommutativity and irreversibility in quantum chaos

University of Tokyo (Ueda group)   Ryusuke Hamazaki

- Irrversibility: traditional probe of chaos



$\hat{\mathcal{O}}$ $\hat{\rho}$ time evolution U_t $\hat{\rho}_t$ perturbation $\hat{A}$ backward evolution $U_t^\dagger$ $\hat{\tilde{\rho}}_t$ $\hat{\mathcal{O}}$

$\hat{\mathcal{O}} = \hat{B}^\dagger \hat{B}$ → We have $I_{AB}(t) = \langle \hat{A}(t)^\dagger \hat{B}^\dagger \hat{B} \hat{A}(t) \rangle$ for final state

- Noncommutativity: new probe of quantum chaos

$$C_{AB}(t) = -\langle |[\hat{A}(t), \hat{B}]|^2 \rangle$$

- Our results: for initially localized states,

$$C_{AB}(t) \simeq I_{AB}(t)$$

Noncommutativity and irreversibility are almost equivalent!

RH, K. Fujimoto and M. Ueda, arXiv:1807.02360.

#6

Phase transitions in the Rényi entropies of large-N interacting vector models in $2+1$ dimensions

- von Neumann entropy can be extracted from Renyi entropies $S_n(A)$ provided the limit $n \to 1$ exists.
- Renyi entropy of a disc-shaped region can be mapped to the free energy, evaluated as a path integral on $\mathbb{H}_2 \times S^1$. $\frac{1}{1-n} ln Tr \rho^n = \frac{2\pi Rn}{n-1} F(\beta = 2\pi nR)$ [CHM].
- We consider the disc to be in the interacting $O(N)$ vacuum and use the large N limit (saddle-point)+ Hubbard Stratonovich to solve.
-

$$(-\partial^2 + m^2 + g\sigma)\phi = 0; \quad \phi \text{ is the vev}$$

$$\phi^2 - \sigma + \frac{1}{Vol(\mathbb{H}_2)} tr\left(\frac{1}{-\partial^2 + m^2 + g\sigma}\right) = 0.$$

- We find strong evidence for an ordering phase transition at $n = 1$. But, what does this imply for the replica trick?

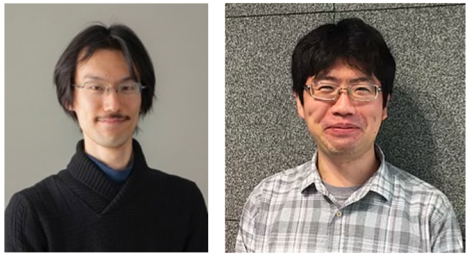
#7

#8

On the Anomaly of the Electromagnetic Duality of the Maxwell Theory

Chang-Tse Hsieh (Kavli IPMU & ISSP, UTokyo)

CTH-Tachikawa-Yonekura, arXiv:**1905.08943**



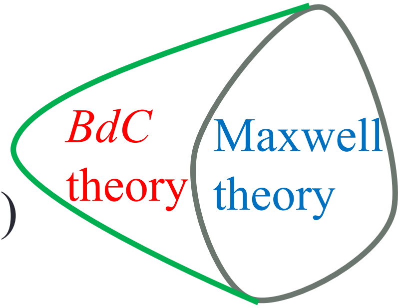
- We consider **4d Maxwell theory** in the situation where going around nontrivial paths in the spacetime involves EM duality transformation

e.g.
$$\mathbf{E}(x+L,y,z)=\mathbf{B}(x,y,z)$$
$$\mathbf{B}(x+L,y,z)=-\mathbf{E}(x,y,z)$$

- We found

*Anomaly of EM duality of Maxwell = **56** times that of a chiral fermion*

- The interpretation is twofold: one is by the **5d bulk SPT** (top. *BdC* theory) phase characterizing the anomaly, and the other is by the properties of a **6d SCFT** (E-string theory)



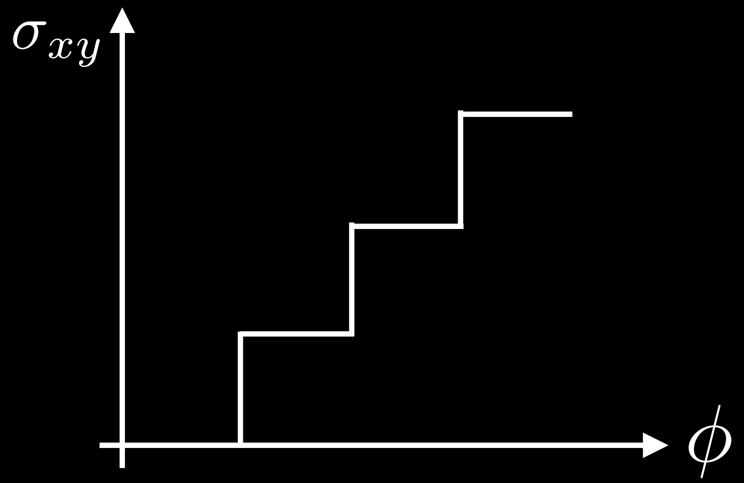
- Our result reproduces, as a special case, the known anomaly of the **all-fermion electrodynamics** discovered in the last few years

#9

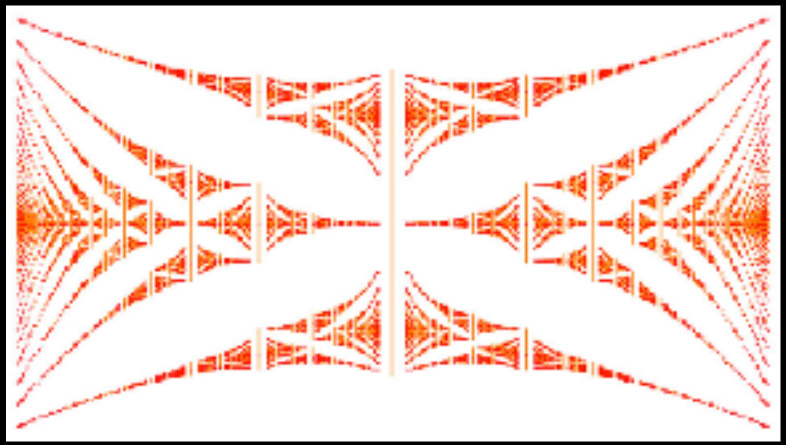
Kazuki Ikeda (Osaka U)

Langlands Duality and Quantum Hall Effect

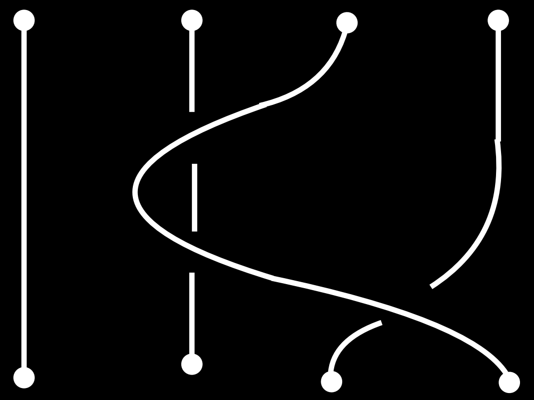
Langlands Duality of Topological Operators



Langlands Duality of Quantum Groups



Langlands Duality of W-algebras



Ann. Phys. 397, 136-150 (2018), J.Math.Phys. 59, 061704 (2018), arXiv:1812.11879 (2018)

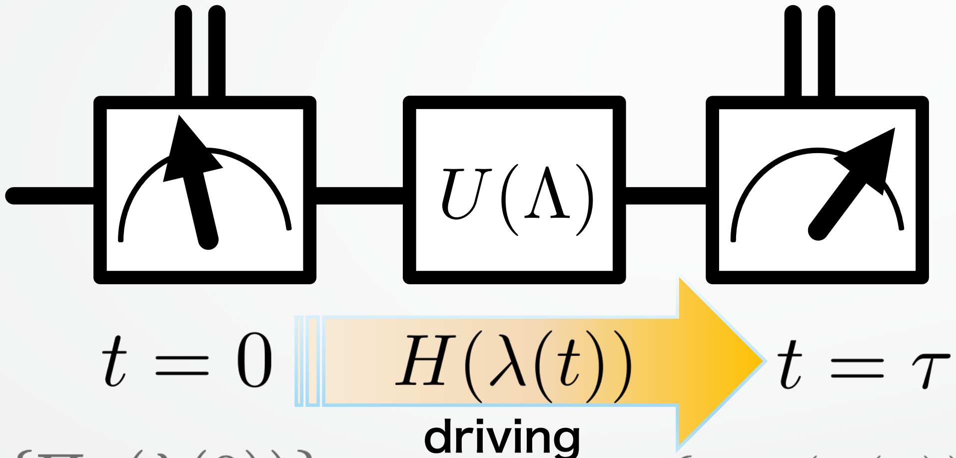
#10

Generalized quantum measurements and quantum work compatible with fluctuation theorems

[Y206 No.10]

[Phys. Rev. A 99, 032117 (2019)]

$$w = -e_n(\lambda(0)) + e_m(\lambda(\tau))$$



$$\rho(0) = \frac{e^{-\beta H(\lambda(0))}}{Z(\lambda(0))}$$

$U(\Lambda)$

$t = 0$ $\quad H(\lambda(t))\quad$ $t = \tau$

driving

- Projective measurement of the Hamiltonian $\{\Pi_n(\lambda(0))\}_n$ $\quad \{\Pi_m(\lambda(\tau))\}_m \Longrightarrow$
- Generic instruments $\quad ? \quad ? \quad \Longleftrightarrow$

Fluctuation theorems

Jarzynski eq.

$$\langle e^{-\beta w} \rangle = e^{-\beta \Delta F}$$

Crooks rel.

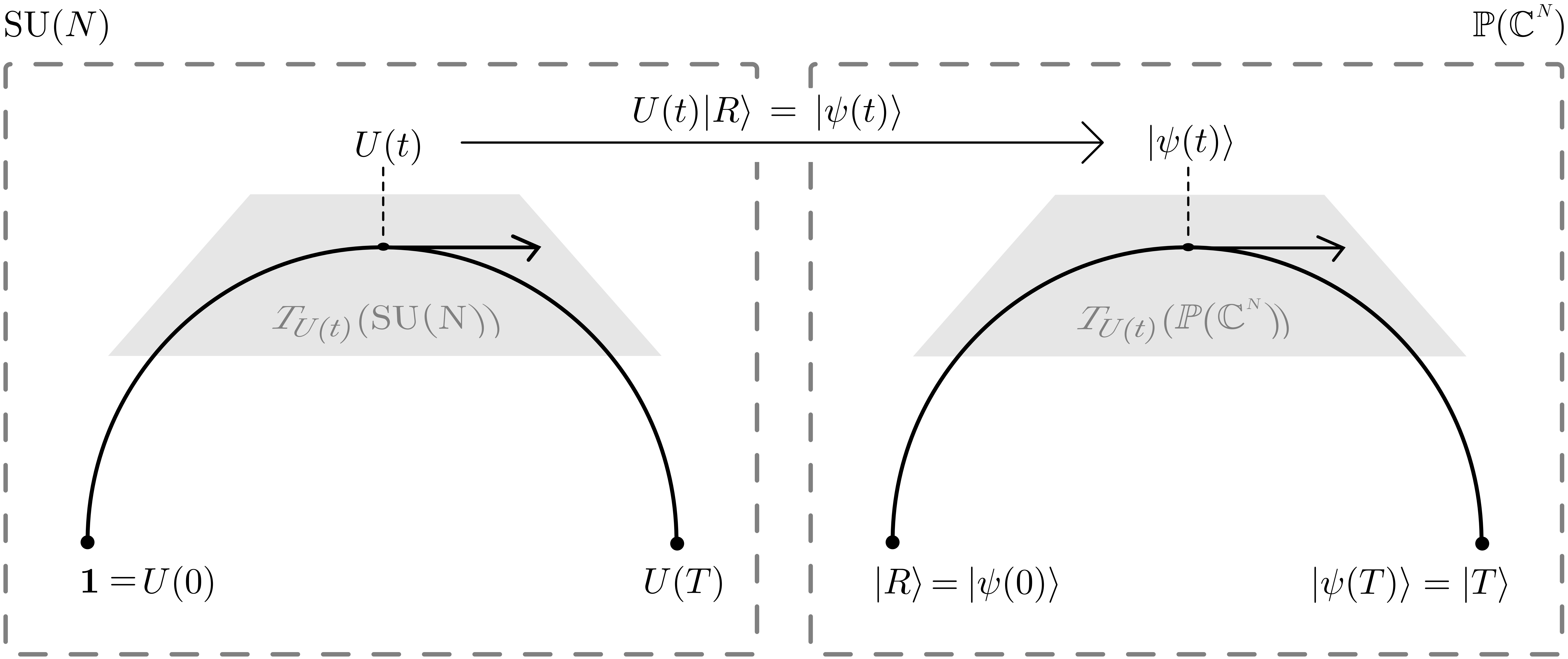
$$p_\Lambda(w) = e^{-\beta(\Delta F - w)} p_{\bar{\Lambda}}(-w)$$

What generalized quantum measurements (instruments) are compatible with fluctuation theorems?

#11

Computational vs. state complexity

Shira Chapman[1] | Lucas Hackl[2,3] | **Joris Kattemölle[1,4]** | Freek Witteveen[1,4] | [1]ITFA, UvA, Amsterdam, The Netherlands | [2] MPQ, MPG, Garching, Germany | [3]MCQST, München, Germany | [4]QuSoft, CWI, Amsterdam, The Netherlands



$\mathrm{SU}(N)$

$\mathbb{P}(\mathbb{C}^N)$

$U(t)\xrightarrow{U(t)|R\rangle \;=\; |\psi(t)\rangle}|\psi(t)\rangle$

$T_{U(t)}(\mathrm{SU(N)})$

$T_{U(t)}(\mathbb{P}(\mathbb{C}^N))$

$\mathbf{1} = U(0)$

$U(T)$

$|R\rangle = |\psi(0)\rangle$

$|\psi(T)\rangle = |T\rangle$

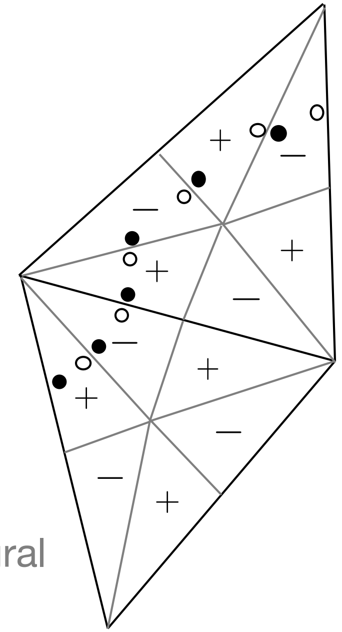
#12

~~Anomaly indicator of rotation symmetry in (3+1)D topological order~~

Fermionic phases of matter on unoriented spacetime

Based on arXiv: 1905.05902

We sometimes consider putting topological phases of matter on **unoriented** spacetime.



Grassmann integral on spacetime

Ex.

- (1+1)d time-reversal SPT phase w/ $T^2=1$

  requires pin_ structure, and classified by $\Omega_2^{\mathrm{pin}-}(\mathrm{pt})=\mathbb{Z}_8$

  generated by $\mathbb{RP}^2$; i.e., $Z(\mathbb{RP}^2)=e^{2\pi i\nu/8}$ detects the classification

Important to formulate **pin$_{+/-}$ TQFT** on unoriented spacetime!

By extending the lattice construction of spin TQFT by Gaiotto & Kapustin,

we can formulate the pin TQFT on lattice, on unoriented spacetime.

Applications:

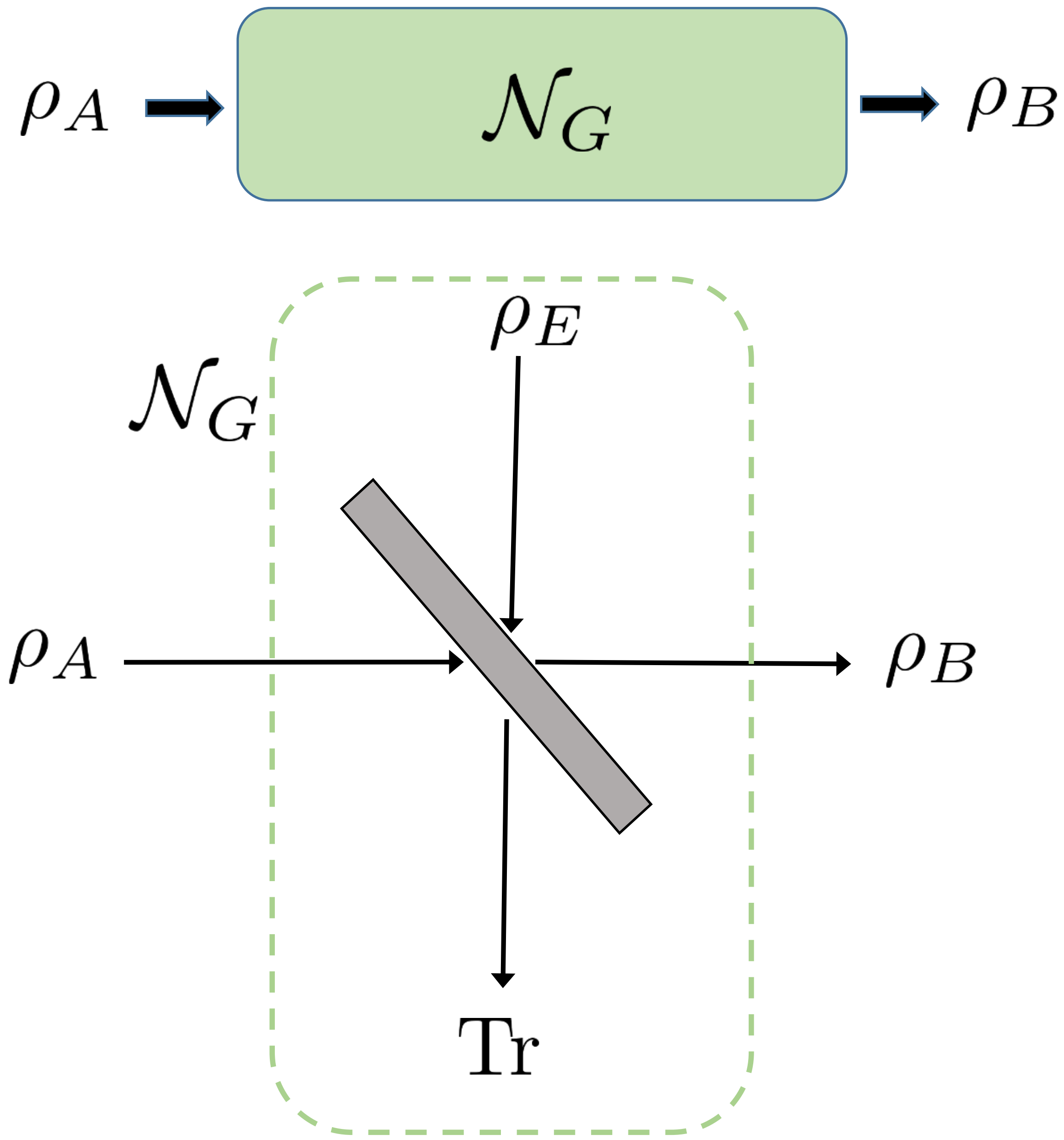
- (1+1)d time-reversal SPT phase w/ $T^2=1$; $\Omega_2^{\mathrm{pin}-}(\mathrm{pt})=\mathbb{Z}_8$
- Time-reversal Gu-Wen SPT phase
- Gapped boundary for time-reversal Gu-Wen SPT phase (see 1905.05391 & 1905.05902)
- Time reversal anomaly of (2+1)d TQFT w/ $T^2=(-1)^F$; $\Omega_4^{\mathrm{pin}+}(\mathrm{pt})=\mathbb{Z}_{16}$

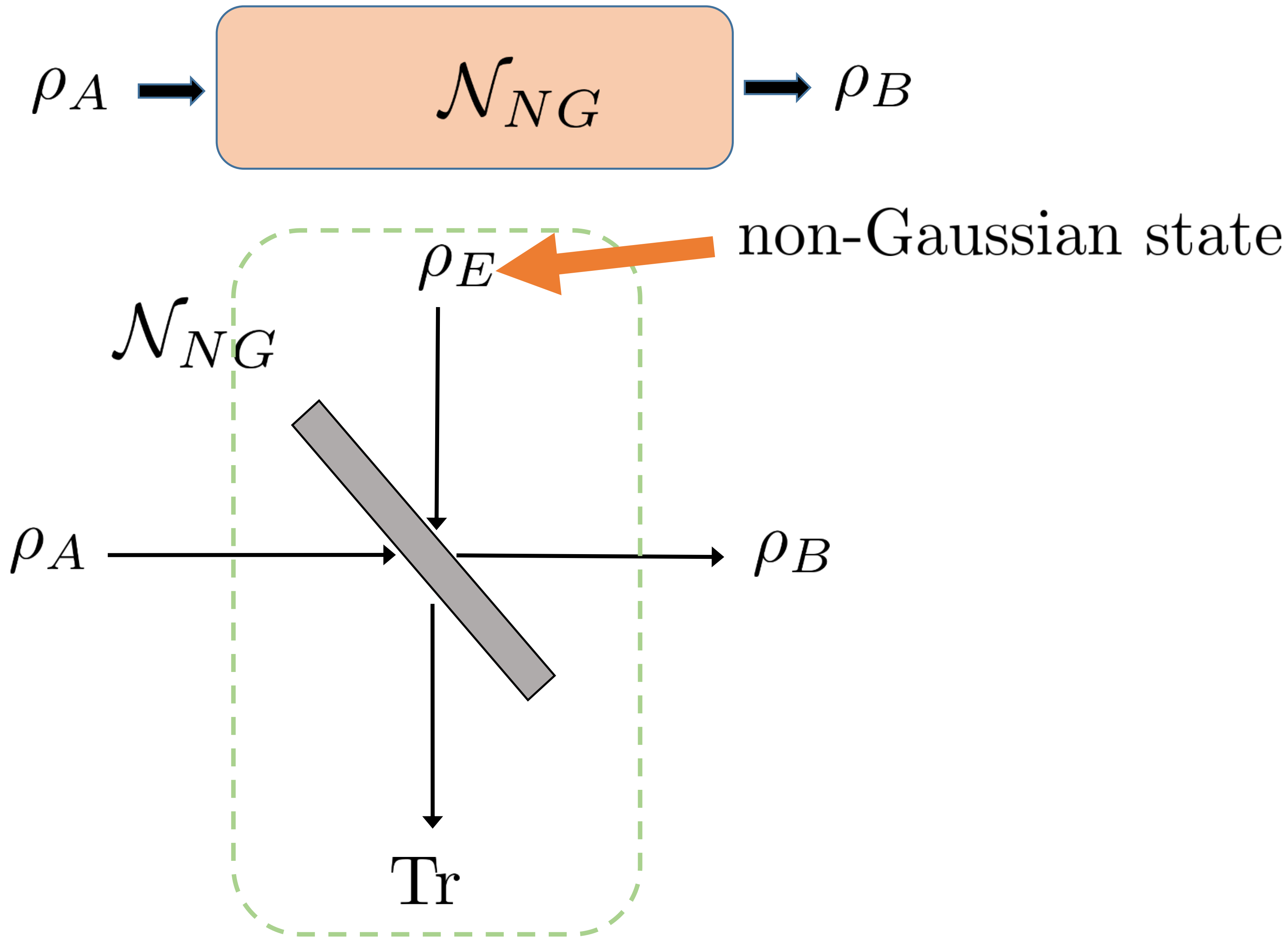
#13

#14

Upper bounds on the quantum capacity for non-Gaussian channels

Youngrong Lim





$$\mathcal{N}_G(\rho_A) = \mathrm{Tr}_E\left[U_{AE}(\rho_A \otimes \rho_E)U_{AE}^{\dagger}\right]$$

$$\mathcal{N}_G^c(\rho_A) = \mathrm{Tr}_B\left[U_{AE}(\rho_A \otimes \rho_E)U_{AE}^{\dagger}\right]$$

$$\mathcal{Q}(\mathcal{N}) = \lim_{n\to\infty}\sup_{\rho_n}\frac{I_c(\mathcal{N}^{\otimes n}, \rho_n)}{n},$$

where $I_c(\mathcal{N}, \rho) = H(\mathcal{N}(\rho)) - H(\mathcal{N}^c(\rho))$.

$$(\rho_X, \rho_Y) \mapsto \rho_{X \boxplus_\tau Y} = \mathcal{N}_\tau(\rho_X \otimes \rho_Y), \quad \text{where } \mathcal{N}_\tau(\rho) = \mathrm{Tr}_E U_\tau \rho U_\tau^{\dagger}$$

$$e^{S(\rho_{X_1} \boxplus_\tau \rho_{X_2})/n} \geq \tau e^{S(\rho_{X_1})/n} + (1-\tau)e^{S(\rho_{X_2})/n}$$

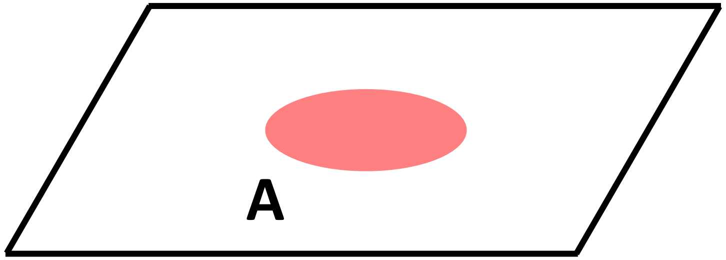
#15

Delocalization of energy by local operators in a ground state of harmonic oscillators

Akira Matsumura (Nagoya Univ.)

☐Reeh-Schlieder theorem in QFT

➡ this theorem relates to nonlocal correlation in QFT



Cauchy surface

polynomial in the field

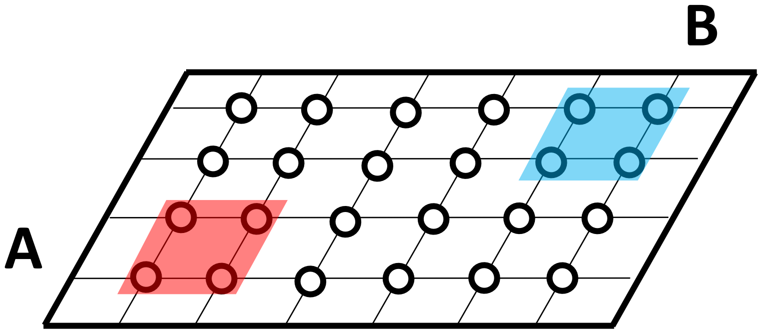
$$\mathcal{O}_{\rm A} = \cdots + \phi(\boldsymbol{x}_1)\phi(\boldsymbol{x}_2)\cdots\phi(\boldsymbol{x}_m) + \cdots$$

$$\boldsymbol{x}_1, \boldsymbol{x}_2, \ldots, \boldsymbol{x}_m \in {\rm A}$$

arbitrary state

$$|\Psi\rangle$$

$$\boxed{\mathcal{O}_{\rm A}\,|0\rangle \approx |\Psi\rangle}$$



To investigate nonlocal property of local operators in a discretized system,

we focus on the energy distribution generated by local operators

#16

Complexity, Entanglement and Topology

Topological Phase Transitions in the SSH model

Based on 1811.05985 by Tibra Ali, Arpan Bhattacharyya, S. Shajidul Haque, Eugene H. Kim and Nathan Moynihan

We investigate the evolution of circuit complexity and entanglement following a quench in a one-dimensional topological system, namely the Su-Schrieffer-Heeger model.

We find that:

- Complexity can detect the various phase transitions
- Complexity can detect revivals in finite-sized quantum systems
- Entanglement entropy saturates *after* the circuit complexity in the SSH model
- Measures of entanglement are more sensitive to topological order than complexity

#17

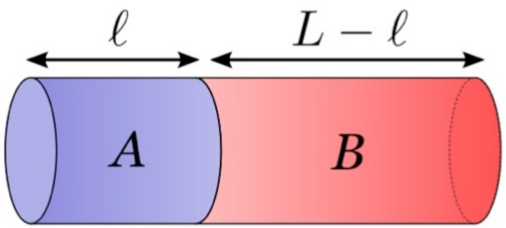
P17

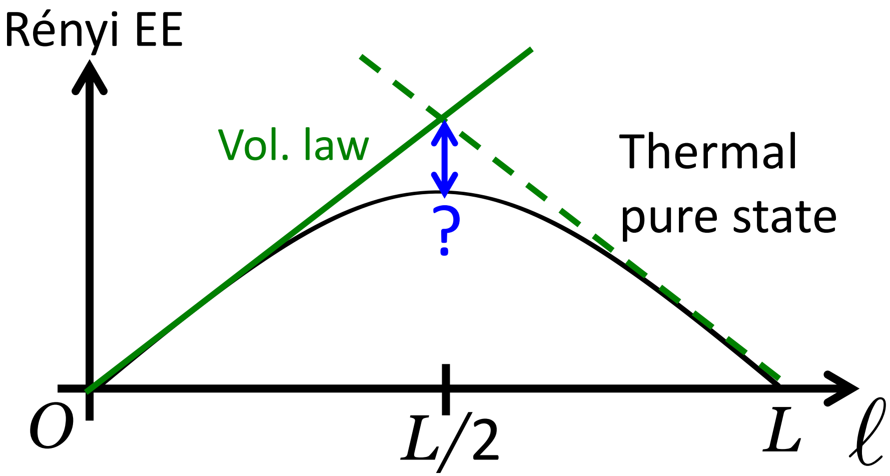
Universality in volume-law entanglement of scrambled pure quantum states

Yuya O. Nakagawa[1], Masataka Watanabe[2], Hiroyuki Fujita[3], Sho Sugiura[4]

[1] QunaSys Inc. [2] AEC, ITP, U. Bern [3] ISSP, U. Tokyo [4] Dept. Phys., Harvard Univ.

$$S_2(l) = \underbrace{l \ln a(\beta)}_{\text{vol. law}} - \underbrace{\ln\left(1 + a(\beta)^{-(L-2l)}\right)}_{\text{deviation}} + \underbrace{\ln K(\beta)}_{\text{offset}}$$





	non-integrable	interacting integrable	quadratic integrable
Stationary states after quench	○	○	×
Energy eigenstates	△	×	×

S_2 of **scrambled** states obeys formula

Nat. Comm. **9**, 1635 (2018)

#18

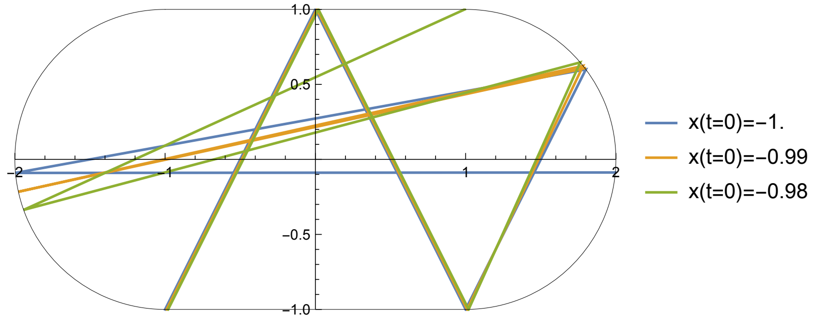
#19

Quantum chaos transition in a model dual to eternal traversable wormhole

Tomoki Nosaka (KIAS)

[1804.09934][1901.06031]

Quantum version of chaos is characterized by

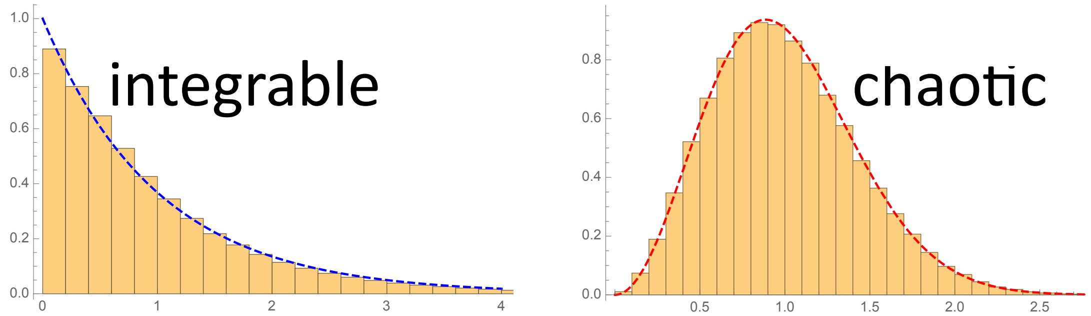


①. Out of Time Ordered Correlator $\langle (i[W(t),V(0)])^2 \rangle \sim e^{\lambda_L t}$

→ quantum Lyapunov exponent λ_L

②. Random Matrix Theory-likeness of energy spectrum

→ distribution of $\{E_i - E_{i-1}\}_{i=2}^{\dim \mathcal{H}}$:



(c.f. Tezuka-san's talk on 5/27)

Our question:

When a system shows quantum chaos/integrable transition, what happens in gravity side?

naive guess: "black hole = chaotic" → C/I transition $\overset{?}{=}$ Hawking-Page transition

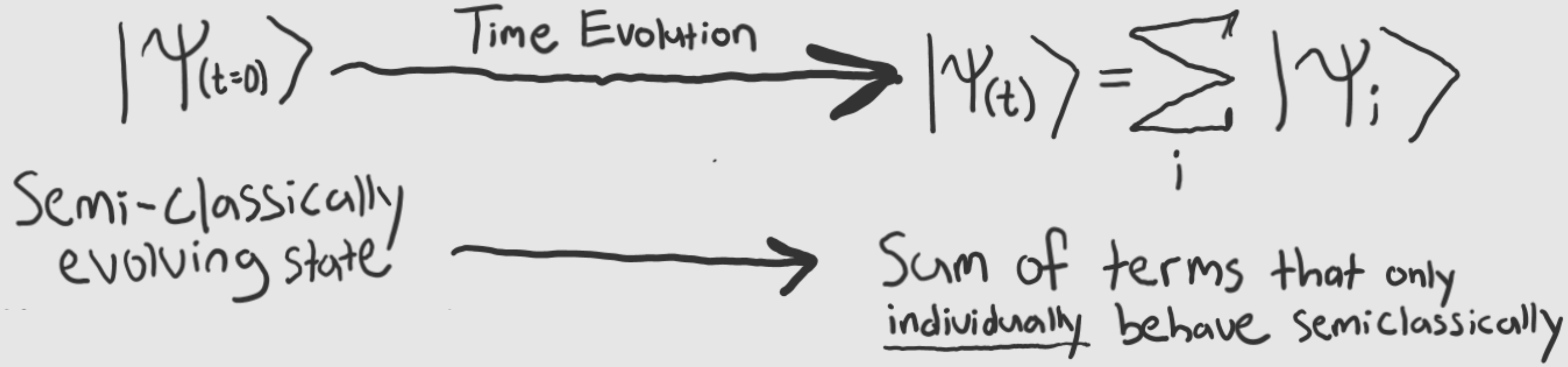
We elaborate ☐ by studying ② in a deformation of SYK model dual to BH/wormhole.

#20

#21

Finding the semiclassical branches of the wavefunction

When a quantum system exhibits classical-ish behavior…



How do you find this decomposition?

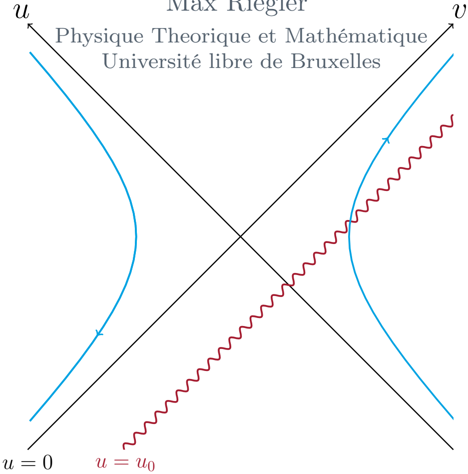
We are developing a tensor-network-based algorithm for identifying this decomposition in many-body body simulations.

With Markus Hauru, Curt von Keyserlingk, Jess Riedel, **Daniel Ranard (@ Stanford University)**

#22

Shockwaves, the Unruh Effect and Black Hole Information Loss

Max Riegler
Physique Theorique et Mathématique
Université libre de Bruxelles



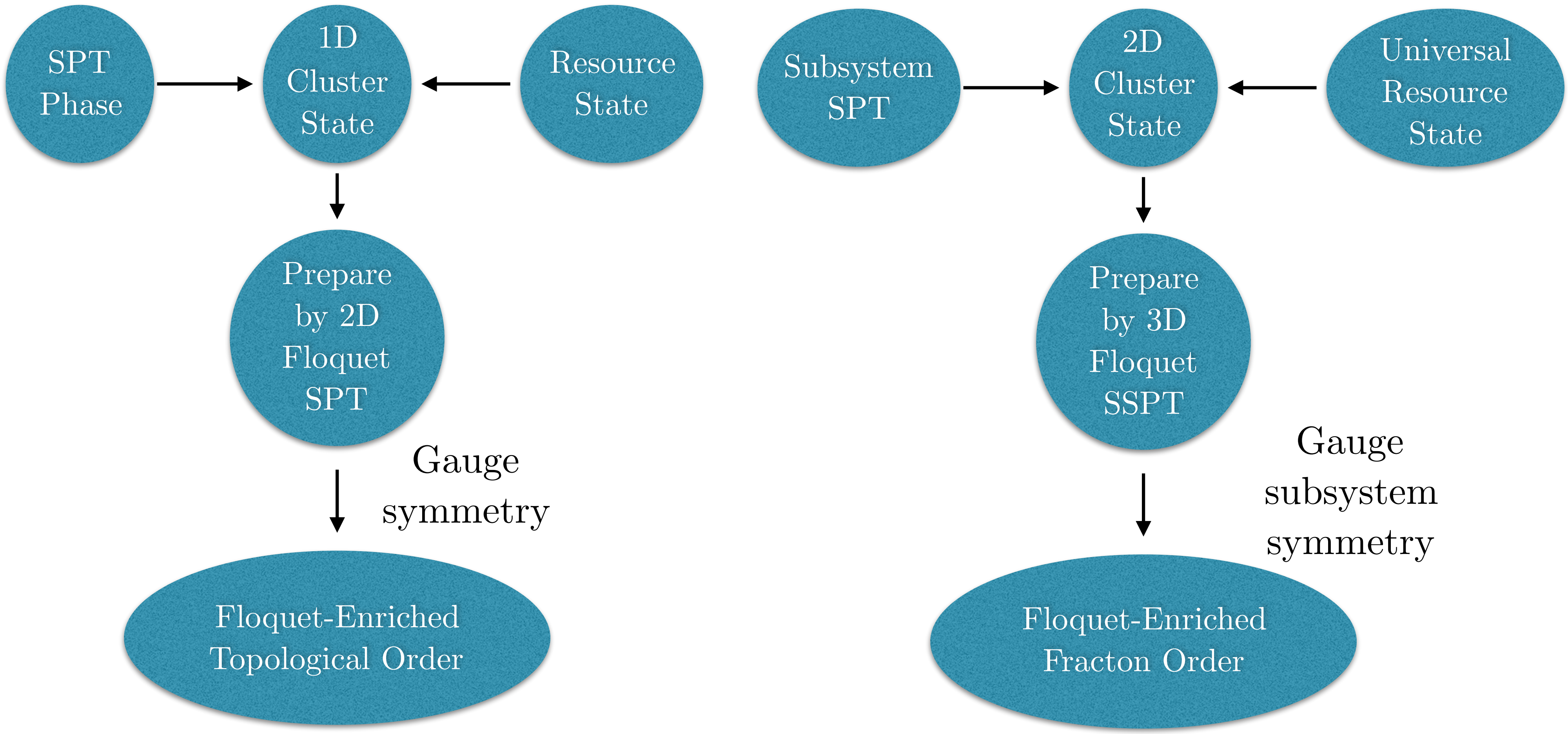
[G. Compère, J. Long, M.R; 1903.01812]

European Research Council
Established by the European Commission

#23

Symmetric Finite-Time Preparation of Cluster States via Floquet Unitary Pumping

Nathanan Tantivasadakarn, Ashvin Vishwanath



SPT Phase

1D Cluster State

Resource State

Prepare by 2D Floquet SPT

Gauge symmetry

Floquet-Enriched Topological Order

Subsystem SPT

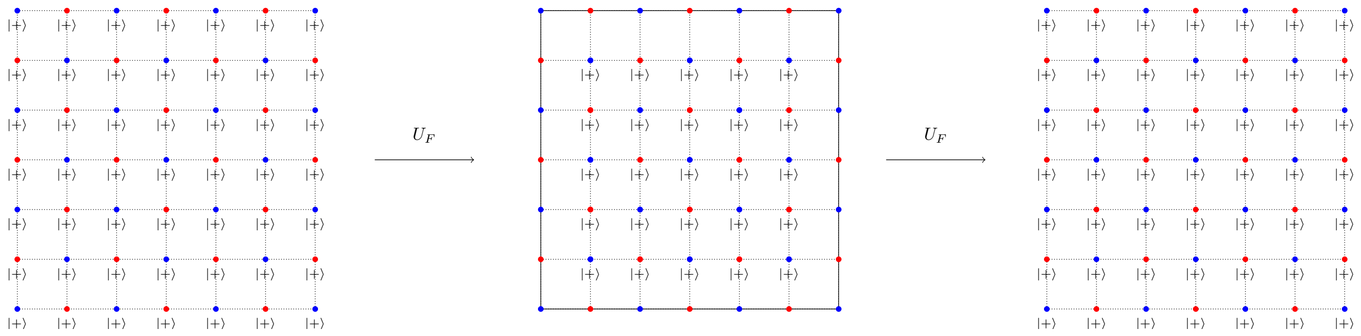
2D Cluster State

Universal Resource State

Prepare by 3D Floquet SSPT

Gauge subsystem symmetry

Floquet-Enriched Fracton Order



#24

Can pure states evolve into mixed states?
— Constructing a Lorentz covariant Non-unitary QFT

Tian Wang (IQIM, Caltech)

June 10, 2019

As we all know, QM is a unitary theory. It has been debated whether one can have a fundamentally non-unitary theory, especially since Hawking discovered his famous Blackhole radiation. In 1983 , Hawking proposed a theory in which pure states can evolve into mixed states, so as to to solve the Blackhole information paradox. This received several criticism, most famously the attack from Banks, Peskin and Susskind in 1984, based on Locality. Srednicki also pointed out the inconsistency with Lorentz covariance (with errors).

Here I present a Lorentz covariant Non-unitary QFT. In Heisenberg picture, the most general CPTP maps are

$$D_s[A(x,t)] = e^{s_\mu L^\mu} A(x,t)$$

where s is a (time-like) Lorentz four vector parametrizing evolution, and L^μ are the Lorentz covariant evolution generators

$$L^\mu A = -i[P^\mu, A] + \int \frac{d^3p}{(2\pi)^3 2\omega_p} \gamma_{ab} p^\mu \left((T^{\alpha\beta})^\dagger_a(\vec{p}) A (T_{\alpha\beta})_b(\vec{p}) + \frac{1}{2}\{(T^{\alpha\beta})^\dagger_a(\vec{p})(T_{\alpha\beta})_b(\vec{p}), A\} \right)$$

Here $T^{\alpha\beta}(\vec{p})$ are momentum dependent jump operators, and double index imply summation, with Greek letters dedicated for Lorentz index.

This theory has the following properties,

Lorentz covariance:

$$U(\Lambda) D_s[A(x)] U(\Lambda)^{-1} = D_{\Lambda s}[A(\Lambda x)]$$

semi-group structure:

$$D_{s_1}[D_{s_2}[A(x,t)]] = D_{s_1+s_2}[A(x,t)]$$

More specifically, we study the case where the only jump operators are annihilation operators $a(p)$. This can be thought of as system modes leak into large and refreshing vacuum bath, with the beam splitter interaction Hamiltonian

$$H_{int} = \int \frac{d^3p}{(2\pi)^3 2\omega_p} \omega_p [a^*(p) b(p) + b^*(p) a(p)]$$

This theory can be solved,

$$D_s[\psi(x)] = \int \frac{dp^3}{(2\pi)^3 2\omega_p} a(p) exp[-ipx] exp[-ip(1 - \frac{i\gamma}{2})] + h.c$$

and the two point functions are

$$< D_s[\psi(x)]\psi(x) >= \int \frac{d^3p}{(2\pi)^3 2\omega_p} Exp[-ips(1 - \frac{i\gamma}{2})]$$

Construction of the interacting theory is under process.

#25

#26

#27

Wormhole and the Thermodynamic Arrow of Time

- **Thermodynamic Arrow of Time:**

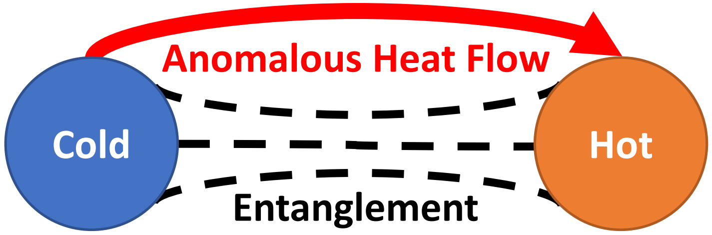
– Zhuo-Yu Xian (ITP-CAS)

Heat spontaneously pass from a hotter system to a colder system.

However, it does not always hold in the present of initial correlation.

- **Anomalous Heat Flow:**

It is possible that energy can pass from colder system to hotter system by consuming correlation.

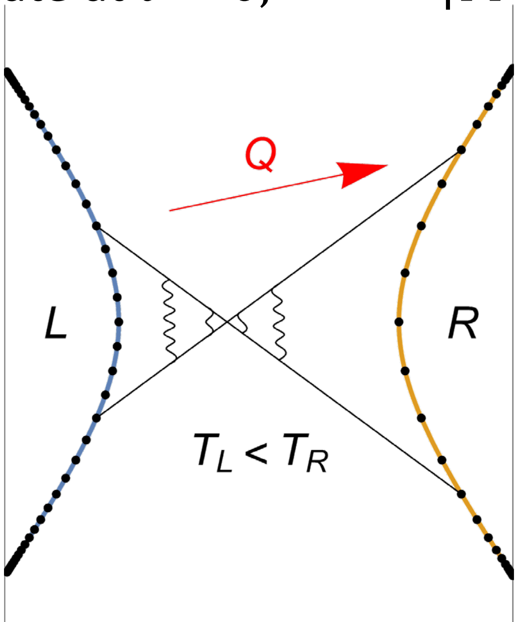


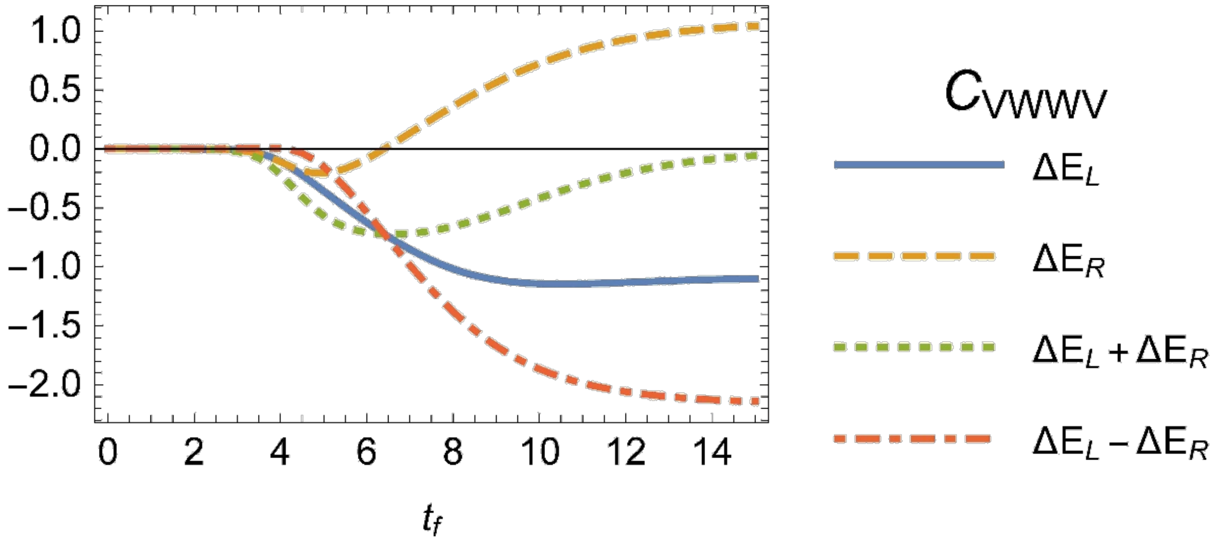
- **AdS2/CFT1:** Hilbert space $\mathcal{H} = \mathcal{H}_L \otimes \mathcal{H}_R$.

Hamiltonian $H_{tot}(t) = H \otimes 1 + 1 \otimes \lambda H + H_I(t)$, with $\lambda > 1$,

where $H_I(t) = \begin{cases} g(V_L W_R - W_L V_R), & t_i < t < t_f \\ 0, & others \end{cases}$, scalar operators $V \neq W$.

State at $t = 0$, $|TFD\rangle = \frac{1}{\sqrt{Z}} \sum_n e^{-\beta E_n/2} |n\rangle_L |n\rangle_R$.



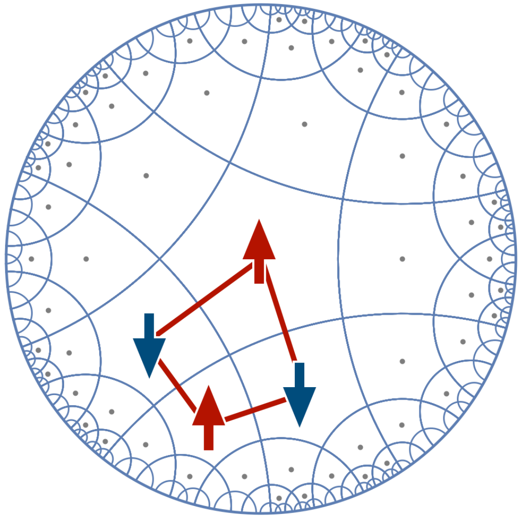


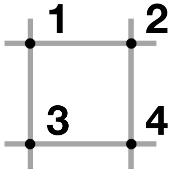
#28

FRACTON STATES AND HOLOGRAPHY

Han Yan, Okinawa Inst. of Sci. and Tech.

Phys. Rev. B 99, 155126 and arXiv:1906.02305

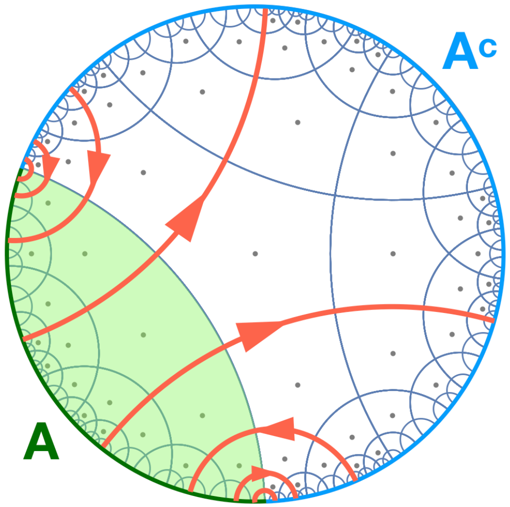




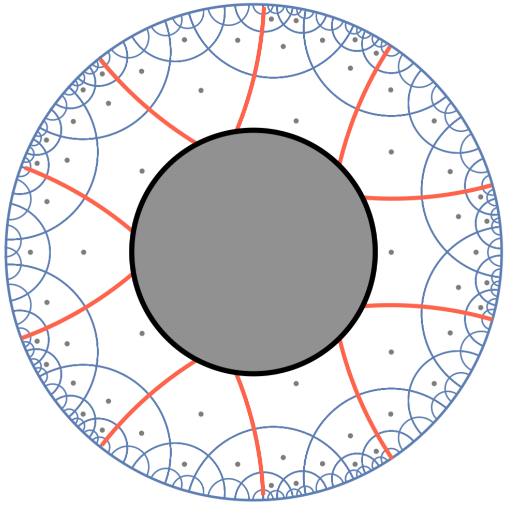
$$\mathcal{O}_p = \prod_{i=1}^{4} S_i^z$$

$$\mathcal{H}_{\text{cl}} = -\sum_p \mathcal{O}_p$$

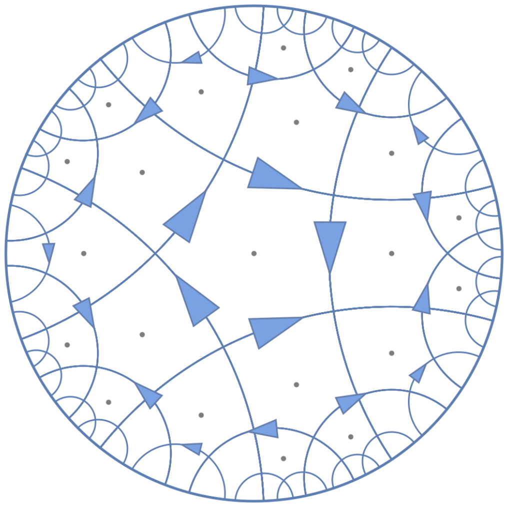
Motivated by fracton states of matter



Obeys RT-formula and subregion duality — key properties of holography



A naively defined black hole has the correct entropy



Equivlaent to another holographic construction — bit-thread model

#29

No. 29

Bell Inequality in the Holographic EPR Pair and the String Worldsheet in AdS

YUKAWA INSTITUTE FOR THEORETICAL PHYSICS

CGP

Poster by: Yun-Long Zhang (YITP): June 12@Y306

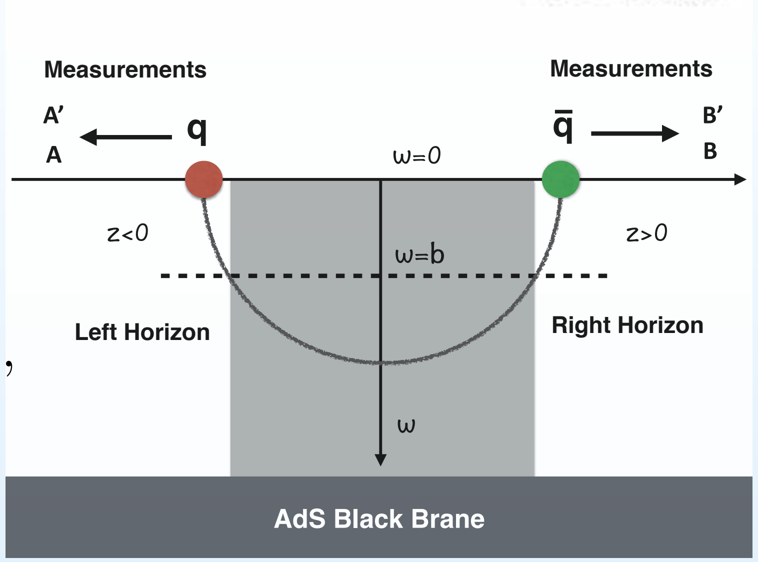
CHSH formula $\langle C\rangle = \langle AB\rangle + \langle AB'\rangle + \langle A'B\rangle - \langle A'B'\rangle,$

For Quantum System $|\langle C\rangle| \leq 2\sqrt{2}$

For Classical System $|\langle C\rangle| \leq 2$

$$|\psi_s\rangle = \frac{1}{\sqrt{2}}(|\uparrow\rangle\otimes|\downarrow\rangle - |\downarrow\rangle\otimes|\uparrow\rangle),$$

$$A = \vec{n}_A\cdot\vec{\sigma},\ \ A' = \vec{n}_{A'}\cdot\vec{\sigma},$$
$$B = \vec{n}_B\cdot\vec{\sigma},\ \ B' = \vec{n}_{B'}\cdot\vec{\sigma}.$$



$$\langle C_{\mathcal{F}}\rangle = \langle A_{\mathcal{F}}B_{\mathcal{F}}\rangle + \langle A_{\mathcal{F}}B'_{\mathcal{F}}\rangle + \langle A'_{\mathcal{F}}B_{\mathcal{F}}\rangle - \langle A'_{\mathcal{F}}B'_{\mathcal{F}}\rangle$$
$$= \cos\theta_{AB} + \cos\theta_{AB'} + \cos\theta_{A'B} - \cos\theta_{A'B'}.$$

$$\theta_{AB} = \theta_{AB'} = \theta_{A'B} = \pi/4, \qquad \theta_{A'B'} = 3\pi/4$$

Holographic EPR Pair $\langle C_{\mathcal{F}}\rangle = 2\sqrt{2}.$

$$A_{\mathcal{F}} = (\cos\theta_A\mathcal{F}^x_A + \sin\theta_A\mathcal{F}^y_A)/\langle\mathcal{F}^x_A\mathcal{F}^x_B\rangle^{1/2},$$
$$B_{\mathcal{F}} = (\cos\theta_B\mathcal{F}^x_B + \sin\theta_B\mathcal{F}^y_B)/\langle\mathcal{F}^x_A\mathcal{F}^x_B\rangle^{1/2},$$

$$\mathrm{i}G^{ij}_{AB}(\tau,x) = \langle\mathcal{F}^i_A(\tau,x)\mathcal{F}^j_B(0)\rangle$$

Nambu-Goto action

$$S_{\rm NG} \simeq -\frac{1}{2\pi\alpha'}\int \mathrm{d}r\mathrm{d}t\Big[1 - \frac{1}{2f(r)}(\dot{\mathbf{x}})^2 + \frac{r^4 f(r)}{2}(\mathbf{x}')^2\Big],$$

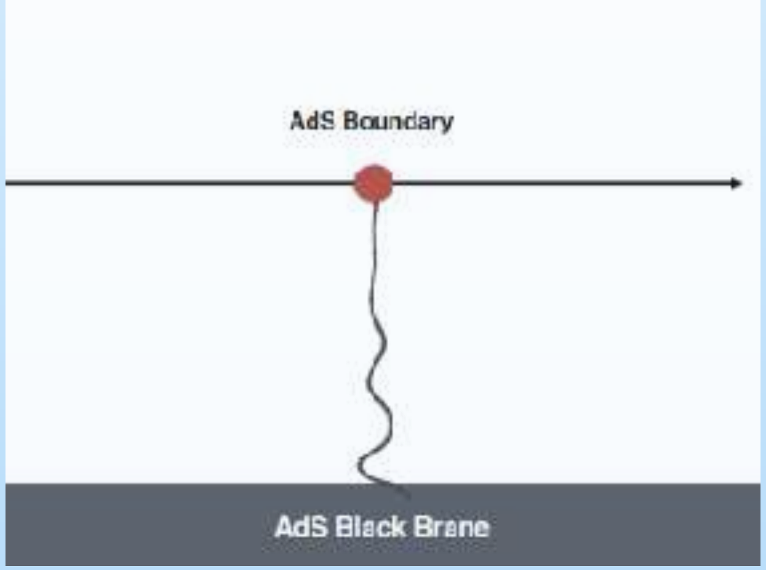
Schwarzian action

$$\mathbf{S}_{\rm Sch} = \frac{1}{2g_s^2}\int_0^\beta \mathrm{d}\tau\left[\left(\frac{\ddot{\mathbf{g}}}{\dot{\mathbf{g}}}\right)^2 - \left(\frac{2\pi}{\beta}\right)^2(\dot{\mathbf{g}})^2\right].$$

$$\mathbf{S}^{(2)}_{\rm ren} = \frac{1}{2g_s^2}\int_0^{ß}\mathrm{d}\tilde{\tau}\left[(\ddot{\tilde{\varepsilon}})^2 - \left(\frac{2\pi}{ß}\right)^2(\dot{\tilde{\varepsilon}})^2\right]$$

String fluctuations in the Bulk

SYK model on the Boundary?



1] Bell inequality in the holographic EPR pair [Chen, Sun, Zhang, on Phys.Lett. B791 (2019) 73-7]
2] The String Worldsheet as the Holographic Dual of SYK State [Cai, Ruan, Yang, Zhang: 1709.06297]

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