Title: Flash Talks - 1 min, 1 slide

Speakers:

Collection/Series: QIQG 2025

Subject: Quantum Gravity, Quantum Information

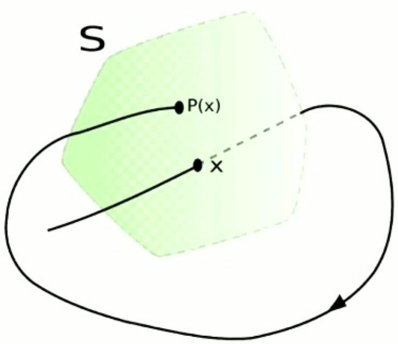
Date: June 25, 2025 - 12:20 PM

URL: https://pirsa.org/25060094

Arithmetic of quantum recurrence in Floquet systems

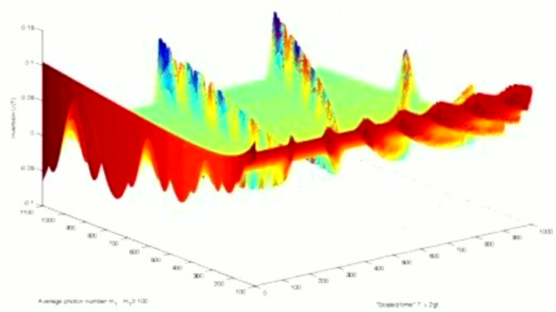
Amit Anand, Dinesh Valluri, Jack Davis, and Shohini Ghose

Poincare recurrence



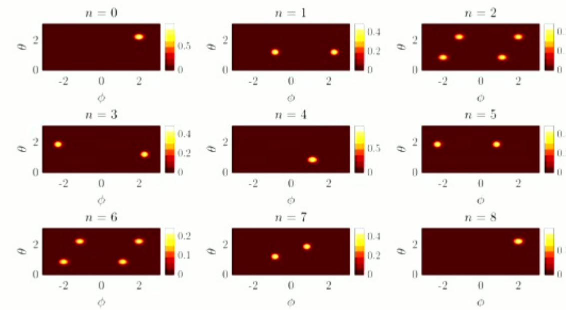
http://en.wikipedia.org/wiki/File:Poincare_map.svg

Quantum recurrence



A. A Karatsuba and E. A Karatsuba 2009 *J. Phys. A: Math. Theor.* **42** 195304

Exact quantum recurrence



Phys. Rev. Research **6**, 023120

UNIVERSITY OF WATERLOO | FACULTY OF SCIENCE

IQC Institute for Quantum Computing

Following the state of an evaporating charged black hole into the quantum gravity regime (arXiv:2503.02051)

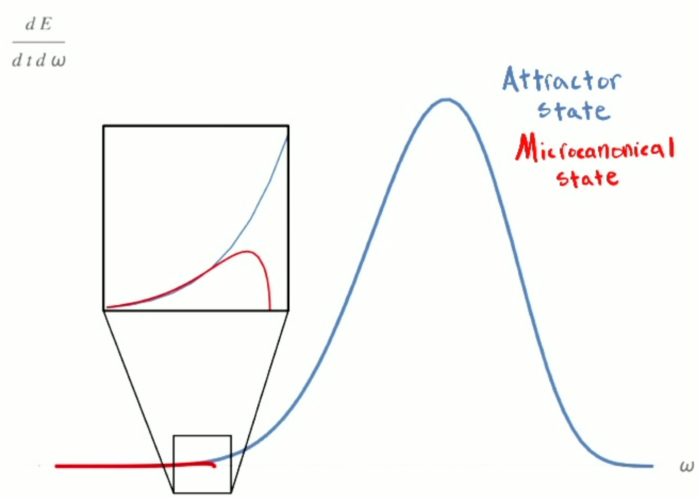
It was recently understood that quantum gravity effects modify the Hawking evaporation rates of near-extremal black holes.[1]

Therefore, they also affect how the black hole state evolves toward extremality.

We study the energy probability density $P(E, t)$ of charged black holes in the very low temperature regime where quantum gravity (Schwarzian) corrections are important.

We find that $P(E, t)$ evolves toward a non-thermal, universal function at long times.

Hawking fluxes calculated in this attractor state can be much larger than those in a microcanonical state with the same expected energy.



[1] Brown et al. 2024; Maulik, Meng, and Pando Zayas 2025.

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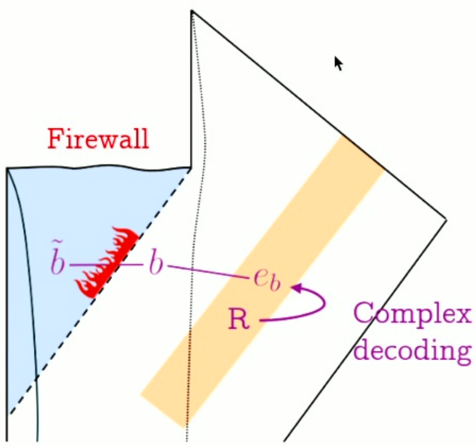
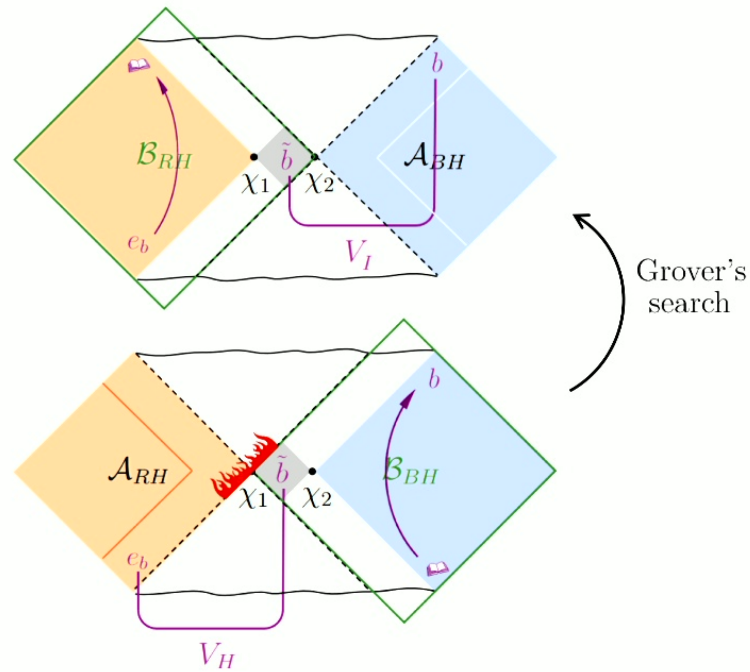
A New Role for Complexity in the Firewall Paradox

Aude Corbeel & Erik Verlinde

(see also poster of Jingxin and Pim)



After Page time



« Safety-barrier » → *« Complexity-wall »*

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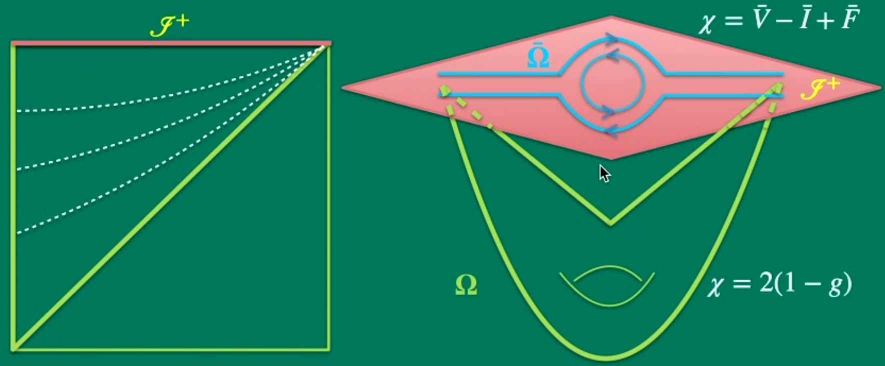
A Complex Proposal for Holographic Cosmology

Complex 't Hooftian Gauge Theory Duals to Flat FLRW Cosmologies



$$Z_{\text{CFT}}[\varphi] \equiv \Psi[\varphi] = \exp\left(- \sum_{n=2}^{\infty} \left[\prod_{a=1}^{n} \int \mathrm{d}^d \mathbf{x}_a \, \varphi(\mathbf{x}_a) \right] \psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) \right),$$

where $\psi_n(\mathbf{x}) \equiv \psi_n(\mathbf{x}_1, \ldots, \mathbf{x}_n) = \langle \mathcal{O}(\mathbf{x}_1) \cdots \mathcal{O}(\mathbf{x}_n) \rangle = - \left. \dfrac{\delta^n \log \Psi[\varphi]}{\delta\varphi_{\mathbf{x}_1} \cdots \delta\varphi_{\mathbf{x}_n}} \right|_{\varphi=0}$

Bulk unitary time evolution, $U^\dagger U = \mathbf{1} \implies \mathbf{RR}$

$$\mathbf{RR}: \quad \left[\psi_n(\mathbf{x}\,;\,\Omega)\right]^* = \psi_n(-e^{i\pi}\mathbf{x}\,;\, e^{-i\pi}\Omega)\,.$$

Suppose boundary theory at $\mathscr{J}^+$ is a $U(N)$ gauge theory with adjoint representations on the boundary and 't Hooft coupling $\lambda = g^2 N$

$$I = \frac{N}{\lambda} \int d^d x \, \mathrm{tr}(\ldots) \; .$$

If this admits a string-theoretic bulk dual, its perturbative expansion corresponds to a genus expansion in the worldsheet topology.
In the 't Hooft limit ($\lambda \gg 1$ fixed, $N \to \infty$), Feynman diagrams in double-line notation are weighted by N^χ, where $\chi = \bar{V} - \bar{I} + \bar{F}$, is the Euler characteristic. This matches the bulk string expansion, where each genus-g worldsheet contributes $g_s^{2(g-1)}$ with string coupling $g_s \sim 1/N$.

$$\mathbf{RR} \implies N \propto e^{\frac{i\pi}{4}(d-1+2m)}, \quad \lambda \propto e^{\frac{i\pi}{2}(d+2n)},$$
$$N^2 \propto e^{\frac{i\pi}{2}(d-1+2m)}, \quad g^2 \propto e^{\frac{i\pi}{4}(d+1+4n-2m)}, \quad \text{where } m, n \in \mathbb{Z}\,.$$

$$\therefore \quad \lambda \in \mathbb{R} \iff d \in 2\mathbb{Z}, \text{ but } N \in \mathbb{R} \iff d \in 2\mathbb{Z}+1\,.$$

Hence, in holographic cosmology, **NO UNITARY** 't Hooftian theory is dual to a flat FLRW cosmology with bulk unitary time evolution!

Ayngaran Thavanesan (at735@cantab.ac.uk)

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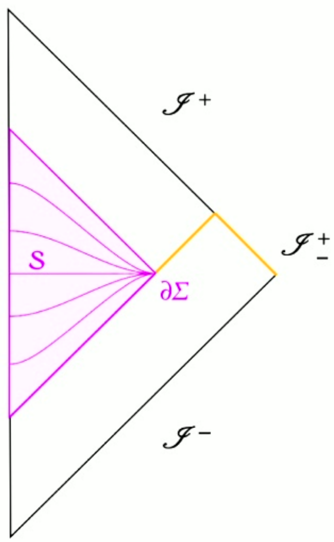
THE AXIOMS OF AQFT FOR GAUGE THEORY ARE FRAME DEPENDENT

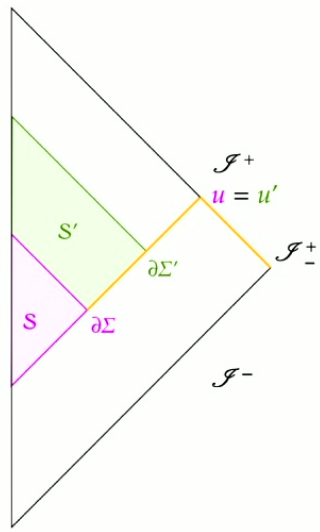
Gonçalo Araujo-Regado[a], Alok Laddha[b], Philipp A. Höhn[a], Bilyana Tomova[a] (Ongoing work)

[a]Okinawa Institue of Science and Technology, [b]Chennai Mathematical Institute

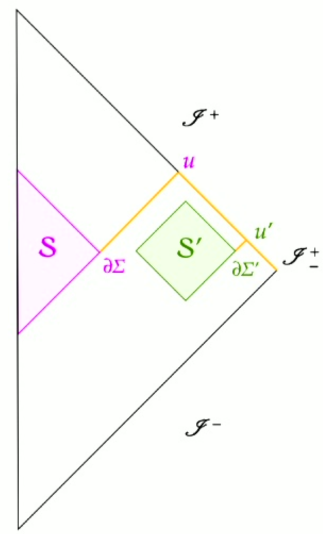
Dressing:



Isotony



Micro-causality



More Holographic Scattering and Non-Minimal RT surfaces

Caroline Lima (with Jacqueline Caminiti and Robert C. Myers)

- How do the correlations between boundary degrees of freedom relate to the dynamics in the bulk?
- We look into bulk-only scattering processes in spinning conical defect and star geometries

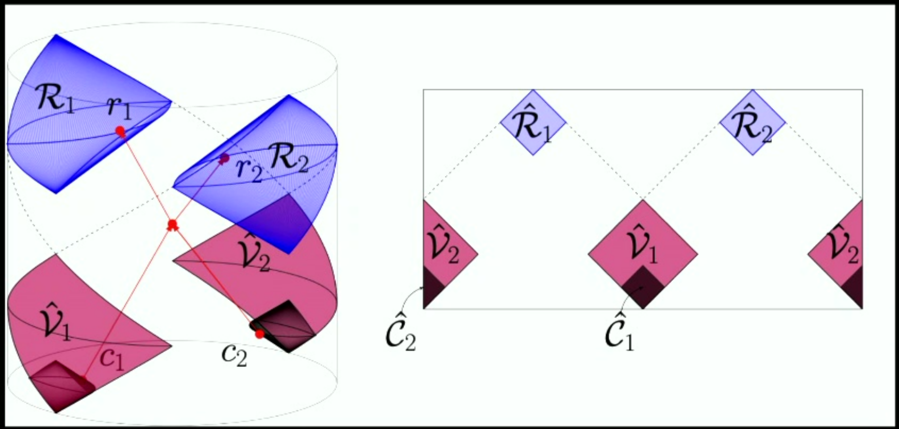


Figure extracted from A. May. Holographic quantum tasks with input and output regions. JHEP, 2021(8):55.

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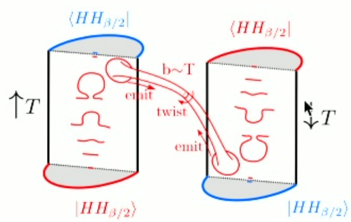
Chuanxin Cui

Firewalls in JT gravity with matter

[2412.1102]

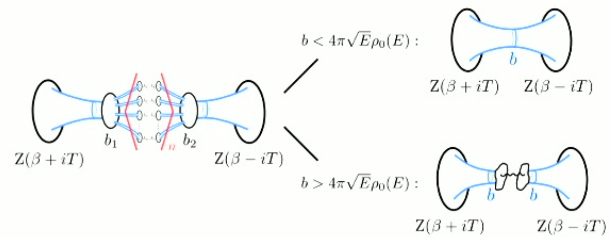
Saad's wormhole

$T_{thouless} < T < T_H$



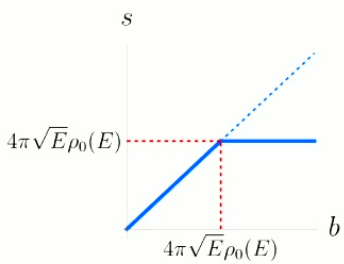
$\mathcal{O}(T)$

Baby universes ending on effective D-branes

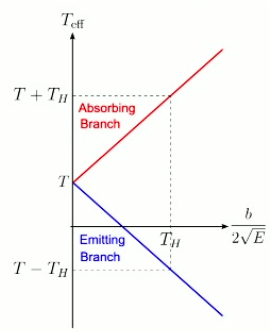


$$\langle Z_B(b_1)Z_B(b_2)\rangle_n \approx \frac{e^{i\sqrt{E}[(\pm)b_1+(\pm)'b_2]}}{b_1b_2}\int_{-\infty}^{\infty} d\omega\, e^{i\frac{\omega}{4\sqrt{E}}[(\pm)b_1-(\pm)'b_2]}\left(\delta(\omega)\rho_0(E)-\frac{\sin[\pi\rho_0(E)\omega]^2}{\pi^2\omega^2}\right)$$
$$\approx \frac{\delta(b_1-b_2)}{b_1b_2}\min\left\{b_1, 4\pi\sqrt{E}\rho_0(E)\right\}.$$

Twist factor cutoff



Effective time slice on handle disk



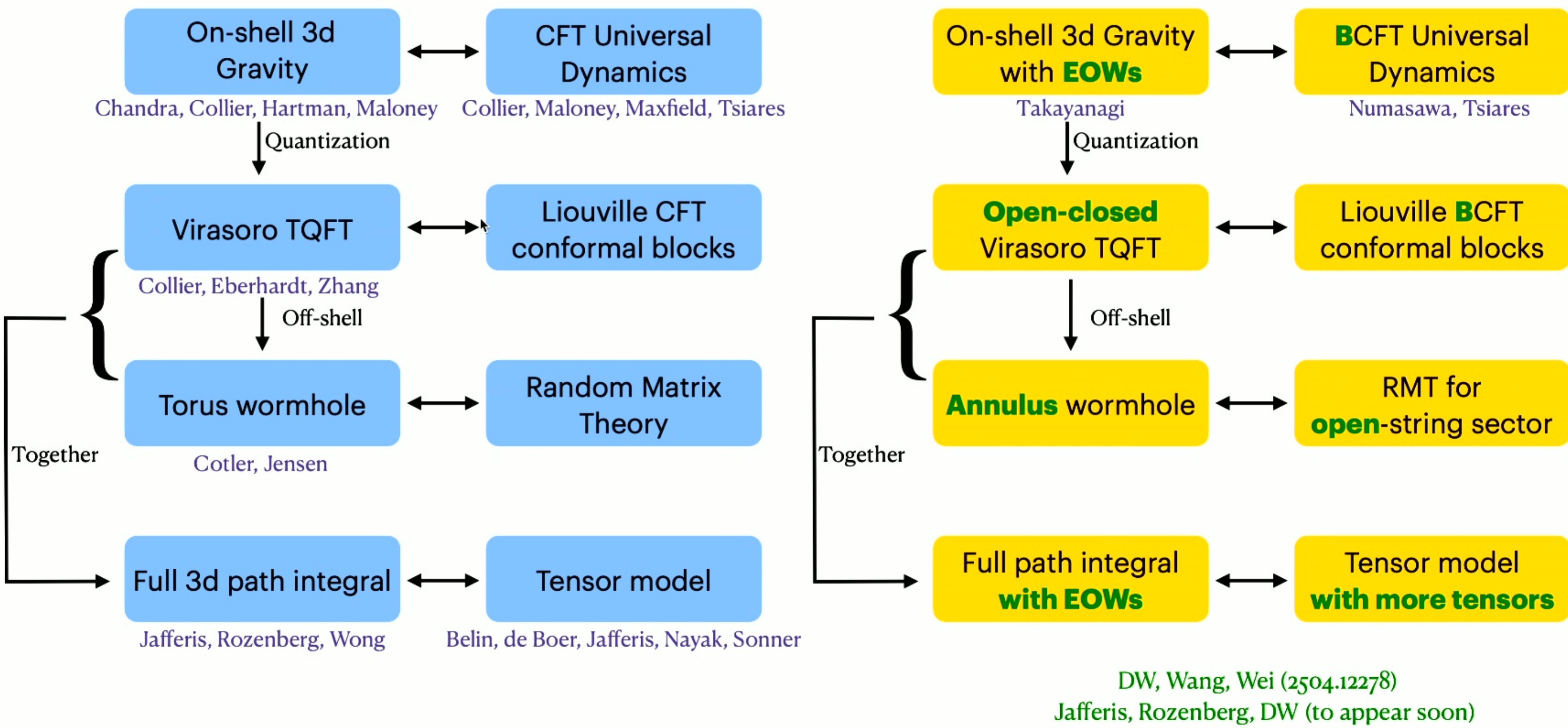
For $T < T_H$: $\mathcal{P}_{\rm BH}(T) = 1 - \frac{T}{T_H} + \frac{T^2}{2T_H^2}$,

$\mathcal{P}_{\rm WH}(T) = \frac{T}{T_H} - \frac{T^2}{2T_H^2}$

For $T \geq T_H$: $\mathcal{P}_{\rm BH}(T) = \frac{1}{2}$, $\mathcal{P}_{\rm WH}(T) = \frac{1}{2}$;

UBC

QIQG, Perimeter Institute, June 2025



Open-closed Virasoro TQFT, 3d Gravity with EOW Branes, and a Random Ensemble of BCFTs   Diandian Wang

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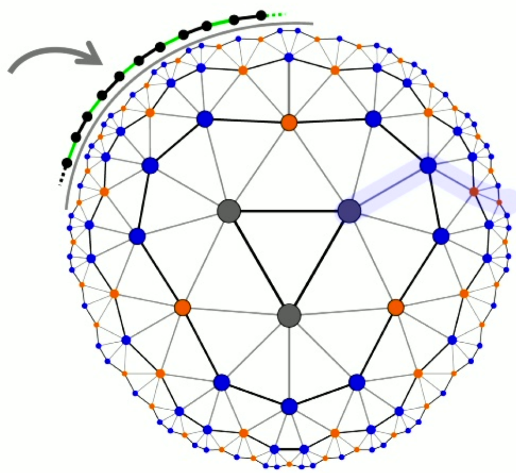
CFT boundaries in discrete-holography models

Dimitris Saraidaris and Alexander Jahn

Question:

Does the **boundary** of the $\{3,7\}$-hyperbolic lattice describe a **continuous CFT**, as a result of its **geometry**?

- we simulate the boundary with a **free-fermionic** or an **interacting** Hamiltonian H
- we study the **critical** properties of the ground states of H



there is a **disorder regime** → critical

↓

in agreement to a **continuous CFT**

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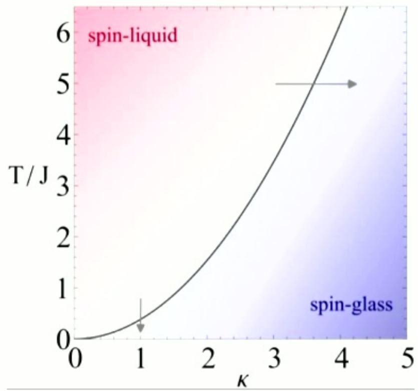
Searching for a holographic dual in spin glasses

Dimitris Saraidaris and Leo Shaposhnik

black hole bound states
↕
glassy models

spectral functions
↓
diagnostics of duality

model with SL/SG transition



how does the spectral function behave as we adiabatically move deep into the spin glass phase??

indications of duality??

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Causality in relativistic quantum interactions without mediators

Eirini Telali [1,2] T. Rick Perche [1,3,4] Eduardo Martín-Martínez [1,2,3,4]

[1]Perimeter Institute for Theoretical Physics, Waterloo, Ontario, N2L 2Y5, Canada
[2]Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada
[3]Department of Applied Mathematics, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada
[4]Institute for Quantum Computing, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada

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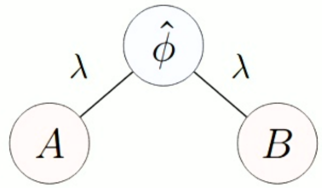
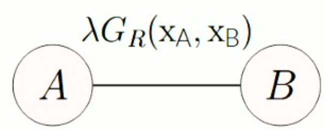
FACULTY OF SCIENCE
Department of Physics and Astronomy

When are the quantum degrees of freedom of fields physically relevant?



(a) Indirect local coupling



(b) Direct relativistic coupling

Quantum sources – Relativistic Quantum interaction - Classical fields

Lessons about Gravity Mediated Entanglement Experiments

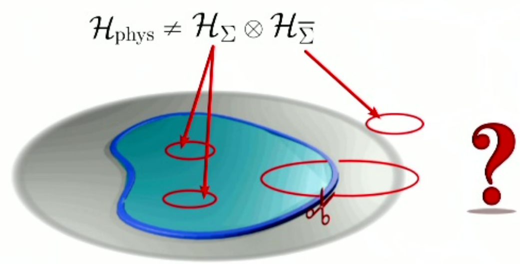
QRF in Lattice Gauge Theory and Subsystem Entropies

G.Araujo-Regado, P.A.Höhn, Francesco Sartini

Motivation: Entanglement entropy in gauge theory ?

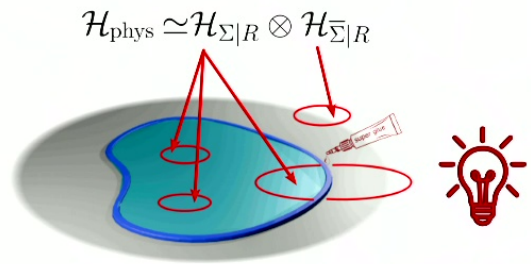
Previous definitions: Non distillable contributions

vN entropy $\neq$ Entanglement



Using Quantum Reference Frames (QRF)

Relationally local factorisation of the Hilbert space



Outcomes: vN entropy $=$ Entanglement

Cost: Frame dependence of susbsystem and entropy

- Previous results by *"forgetting the frame"*
- Hierarchy of entropies

Holographic Entanglement Entropy in the FLRW Universe

2504.10457: Toshifumi Noumi (UTokyo), **Fumiya Sano** (ScienceTokyo, IBS), Yu-ki Suzuki (YITP)

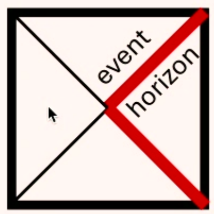
Q. Holographic implication for our universe? ⬅ Holography for a given bulk theory?

Euclidean CFT

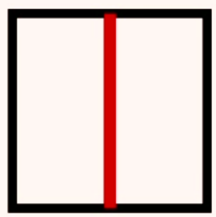
dS/CFT
[Strominger '01]

✓ Euclidean
→ Unitarity?

Looking for unitary QFT



Static patch holography
[Susskind '21]



Half holography
[Kawamoto et al. '23]

✓ Timelike boundary
→ Time direction of QFT

Actual universe is FLRW

FLRW holography
[Nomura et al. '16, Franken et al. '23]

Equation of state $p = w\epsilon$

de Sitter space: $w = -1$

Null energy condition: $w \geq -1$

Our work

✓ Ryu-Takayanagi entropy for {"static patch" holography, half holography} in FLRW

✓ Subadditivity and energy condition

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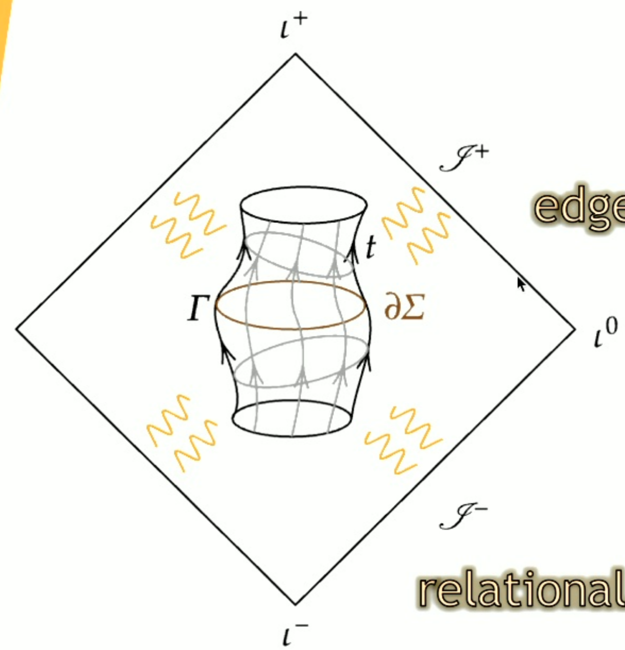
Soft Edges – the link between soft and edge modes

Gonçalo Araujo-Regado

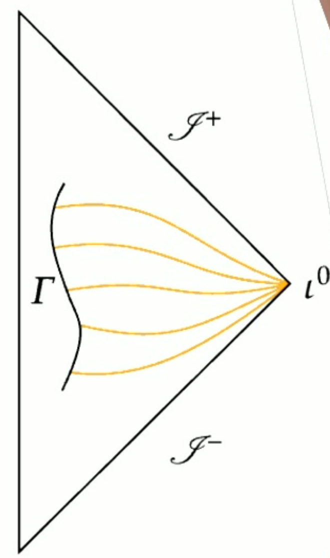


corner symmetries

edge modes

soft modes

relational Goldstone modes



Magic as negativity of the Wigner distribution

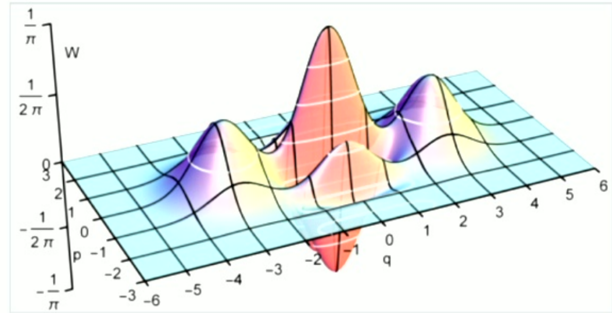
- The Wigner distribution $W(x,p)$ for a pure state is defined as:

$$W(x,p) \stackrel{\text{def}}{=} \frac{1}{\pi\hbar}\int_{-\infty}^{\infty} \psi^*(x+y)\psi(x-y)e^{2ipy/\hbar}\,dy$$

- Discrete version for qudits:

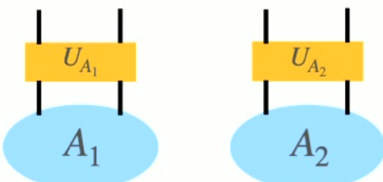
$$W_\psi(u) = \frac{1}{d^n}\mathrm{Tr}(A_u\psi), \qquad A_u = \sum_v P_u P_v P_u^\dagger$$

$$M(\psi) = \log\Big(\sum_u |W_\psi(u)|\Big)$$



Wigner function of a quantum state (Copy from Wikipedia)

Non-local magic is a resource for gravitational back-reaction

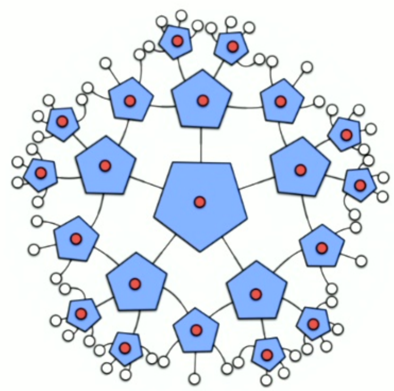


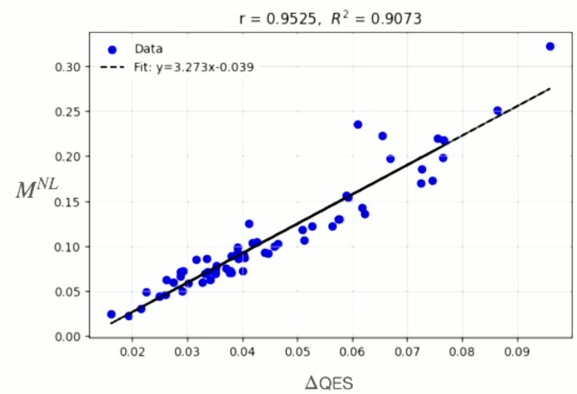
$$M^{(n-\mathrm{NL})}(\psi_{A_1\ldots A_n}) := \min_{U=\otimes_{i=1}^n U_{A_i}} M(U\psi_{A_1\ldots A_n}U^\dagger).$$

- For holographic CFT with $N \to \infty$, non-local magic by the area-tension susceptibility

$$\frac{1}{8}\left|\frac{\partial\mathcal{A}}{\partial\mathcal{T}}\right|_{\mathcal{T}=\mathcal{T}_2} \le 4G^2\mathcal{M}_2^{(NL)}(\psi_{AB}) \le \left|\frac{\partial\mathcal{A}}{\partial\mathcal{T}}\right|_{\mathcal{T}=0}.$$

- For finite N, we consider a toy model of holography: the skewed HaPPY code





Observers seeing gravitational Hilbert spaces

Abstract sources for an abstract path integral

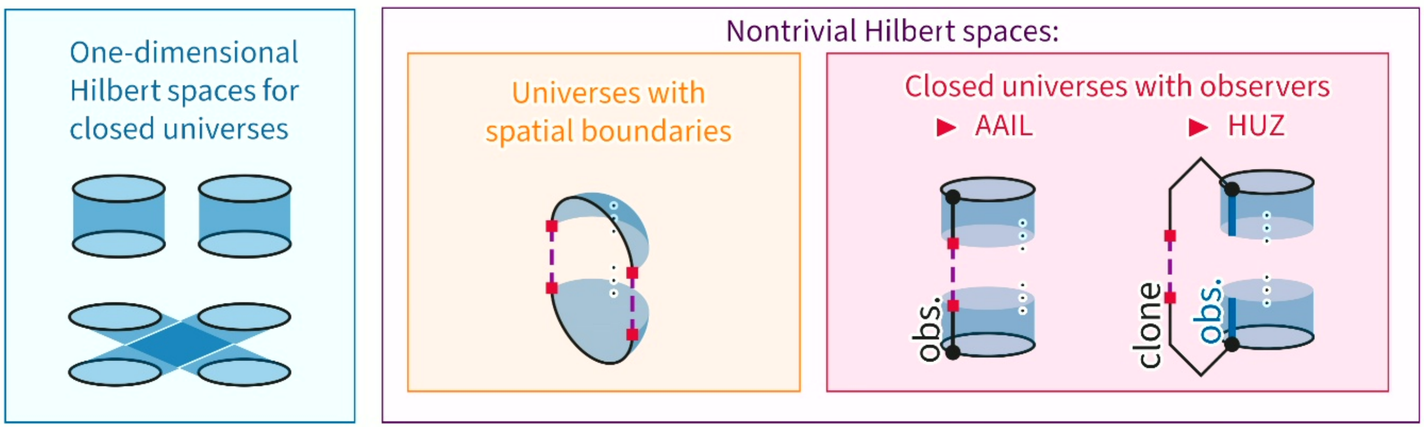
arXiv:2505.15892 [hep-th]

UC SANTA BARBARA
Department of Physics
Hong Zhe (Vincent) Chen

- The gravitational path integral (GPI) leads to a striking result: closed universes have one-dimensional Hilbert spaces.
- There are at least two prescriptions (AAIL and HUZ) for modifying the GPI to recover nontrivial Hilbert spaces associated with observers in closed universes.
- Rather than arguing which, if either, is correct, we instead develop:

Our general framework

Baby universes, α-sectors, abstract gravitational path integrals with abstract (partial) sources



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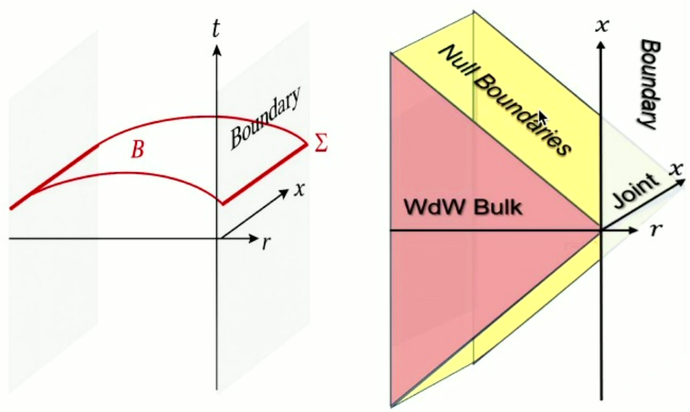
Complexity, scaling, and a phase transition

Jiayue Yang, and Andrew R. Frey (JHEP09(2023)029)

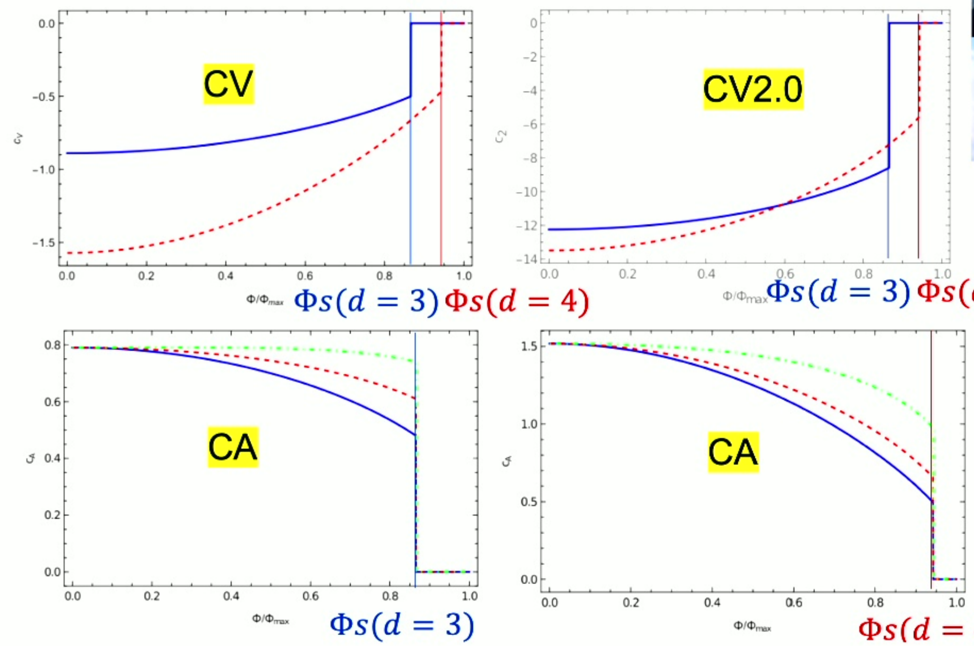
- Holographic complexity

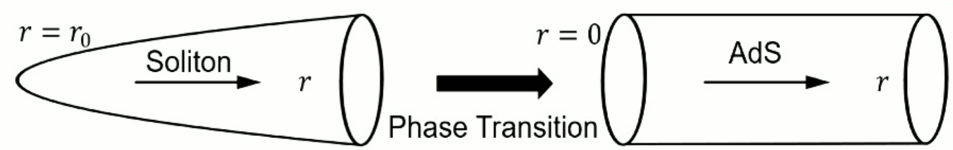


- Same scaling behavior

$$\mathcal{C} \propto \Delta\phi^{-(d-1)}$$

- Same phase transition

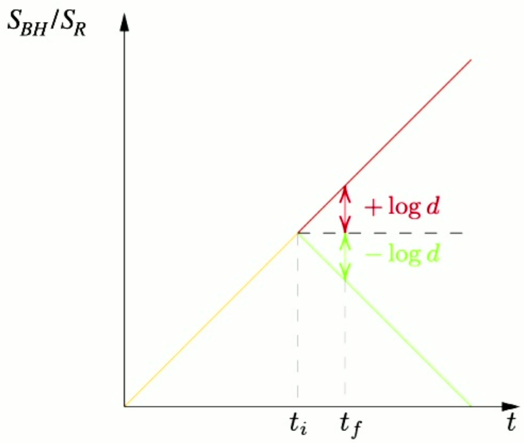


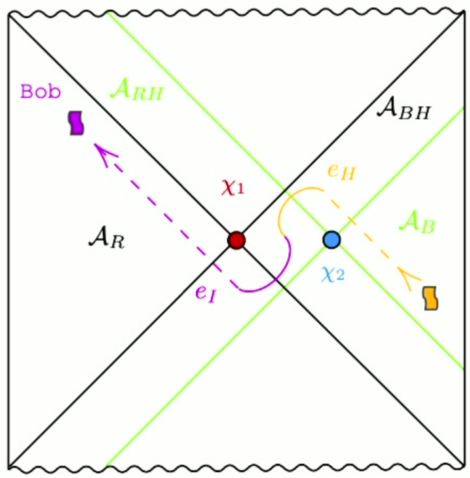


Algebraic description for black hole evaporation

Jingxin Tu[1], Pim van den Heuvel[1], Jeremy van der Heijden[2], Erik Verlinde[1]
1:University of Amsterdam, 2:University of British Columbia

- Algebraic Page curve
- Algebraic Information Recovery





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WÜRZBURG

Non-Locality induces Isometry and Factorisation in Holography

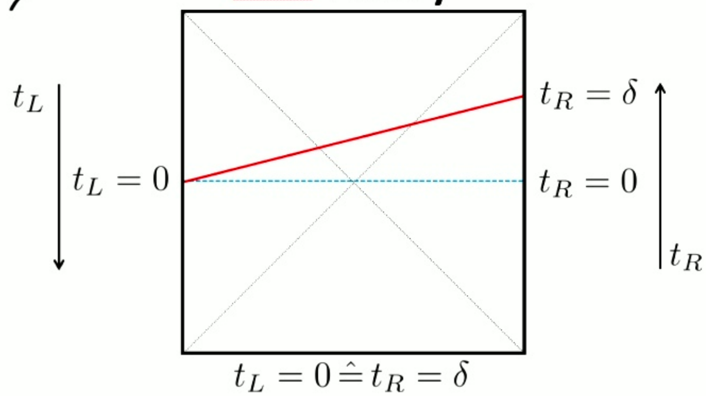
Authors: Souvik Banerjee, Johanna Erdmenger, **Jonathan Karl**
Arxiv: 2411.09616 [hep-th]

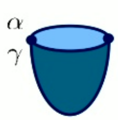
Boundary Theory ⟺ Dual ⟺ Bulk Theory

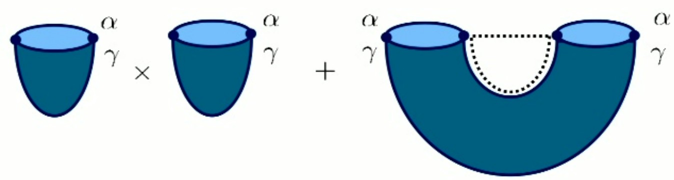
Two copies of a CFT in time-shifted TFD state

$$|\mathrm{TFD}_\alpha\rangle = e^{iH_R\delta}|\mathrm{TFD}\rangle = \frac{1}{\sqrt{Z(\beta)}}\sum_n e^{-\frac{\beta}{2}E_n}e^{i\alpha_n}|n,n\rangle$$

with $\alpha_n = E_n\delta$



$\langle \mathrm{TFD}_\alpha|\mathrm{TFD}_\gamma\rangle_{\text{pert.}} = \delta_{\alpha\gamma} \simeq$  $\Rightarrow$ states span ∞ dim. HS

$|\langle \mathrm{TFD}_\alpha|\mathrm{TFD}_\gamma\rangle|^2_{\text{non-pert.}} = \delta_{\alpha\gamma} + \frac{Z_2}{Z_1} \simeq$ 

- $\Rightarrow$ States span HS of dim $e^{S_{\text{BH}}}$
- $\Rightarrow$ Transition to type I vN algebra with discrete spectrum
- $\Rightarrow$ States contained in factorised HS

QIQG '25

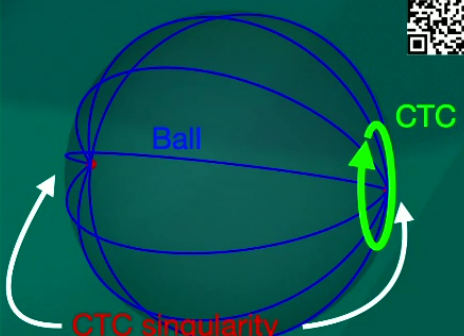
Entropies of gravitational systems from simplicial Lorentzian path integrals

José Padua-Argüelles, PI

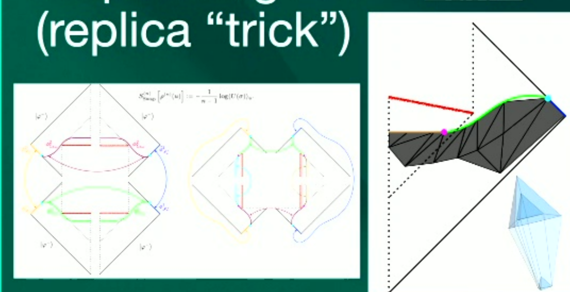
The Euclidean path integral is ill defined, so how can we do gravitational thermodynamics? → We can use the Lorentzian path integral!

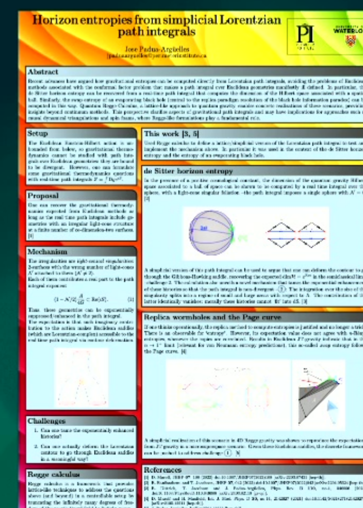
Use lattice-like formulation of GR (Regge Calculus) to implement this in a manageable way

dS horizon entropy



Swap entropy for evaporating BH (replica "trick")





Gravitational entropy is observer-dependent

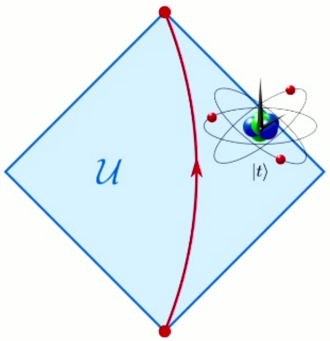
J. De Vuyst, S. Eccles, P. Höhn & J. Kirklin, [2412.15502, JHEP 05(2025)211, 2405.00114]

Generalised entropy formula for a subregion $\mathcal{U}$ of spacetime:

$$S_{\text{gen}}(\mathcal{U}) = \frac{\text{Area}}{4G_{\text{N}}} + S_{\text{QFT}}(\mathcal{U})$$

→**Quantum reference frame** leads to natural regularisation (type II algebra)

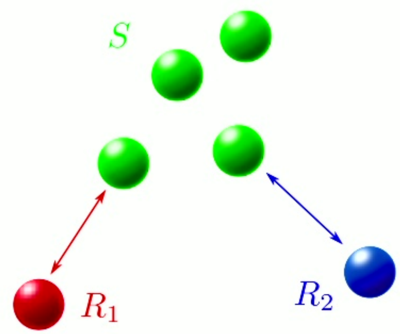
Gravitational entropy with QRFs



$$H = H_S + H_C$$

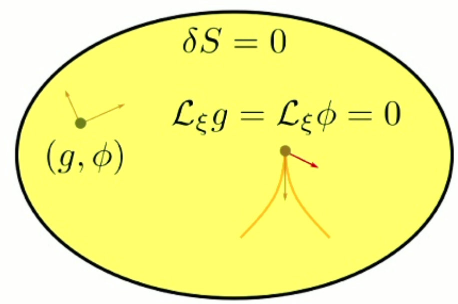
$$(\mathcal{A}_{\mathcal{U}} \otimes \mathcal{B}(\mathcal{H}_C))^H = \langle O_C^\tau(\mathcal{A}_S), e^{-iH_C t}\rangle$$

Subsystem relativity



$$\mathcal{A}^{\text{phys}}_{S|R_1} \neq \mathcal{A}^{\text{phys}}_{S|R_2}$$

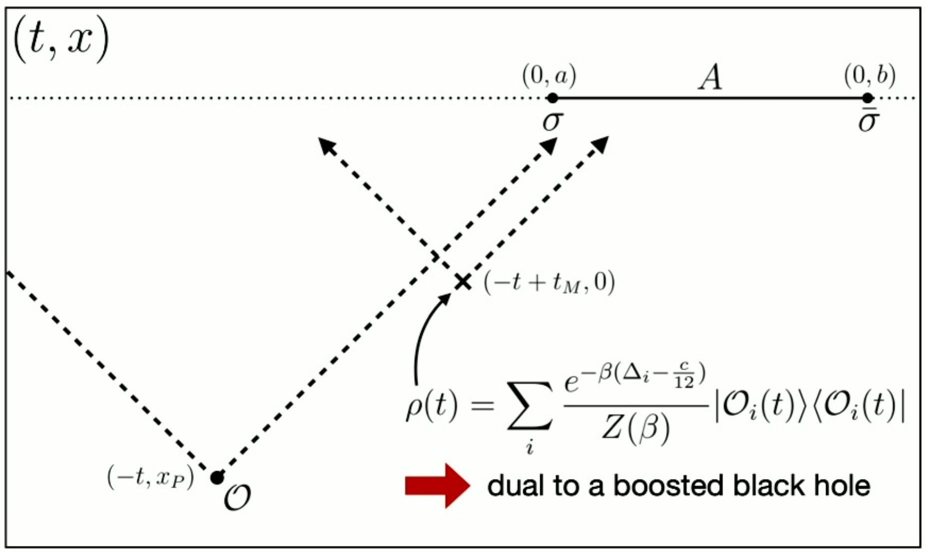
Linearisation instability

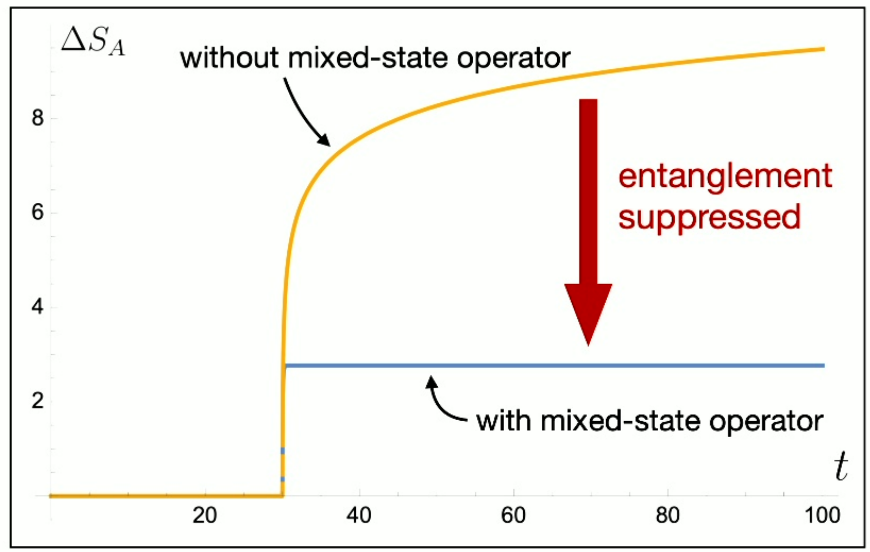


$$\int_\Sigma (-2G^{(2)}_{\mu\nu}(h,h) + T^{(0)}_{\mu\nu})\xi^\mu_s \varepsilon^{(0)\nu} = 0$$

Entanglement Suppression Due to Black Hole Scattering

Kazuki Doi, Yukawa Institute of Theoretical Physics
(Based on work in preparation with T. Takayanagi)





Probing de Sitter space using CFT states

Kotaro Shinmyo (YITP)

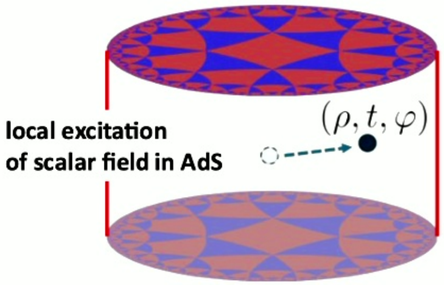
- Holpgraphy argues $Z_{d+2 \text{ Gravity}} = Z_{d+1 \text{ QFT}}$

→ All observables correspond!

Q. How do we reconstruct the $d + 2$ dim. gravity from $d + 1$ dim. QFT?

- In AdS_3/ CFT_2, we can analyze AdS_3 spacetime by dual CFT_2 states.

[Miyaji-Numasawa-Shiba-Watanabe-Takayanagi 2015]



dual

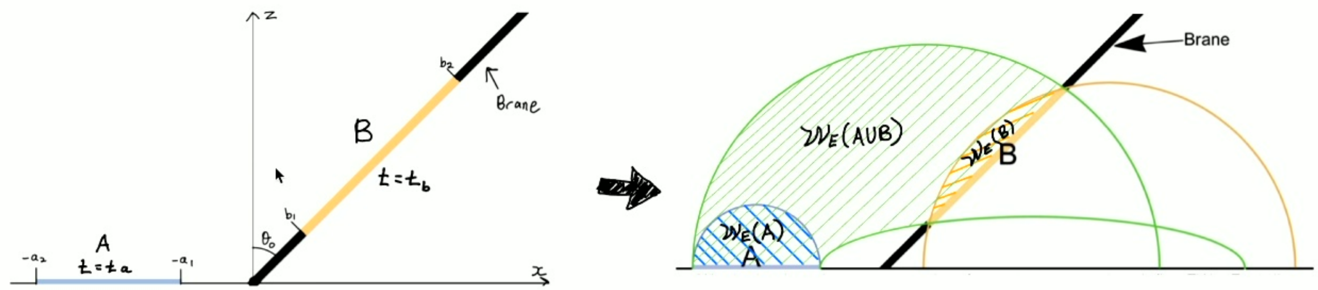
$$\longleftrightarrow \quad |\Psi^{(\Delta)}_{\mathrm{AdS}}(\rho, t, \varphi)\rangle \in \mathcal{H}_{\mathrm{CFT}}$$

- **We successfully construct the CFT_2 states probing dS_3 spacetime!**

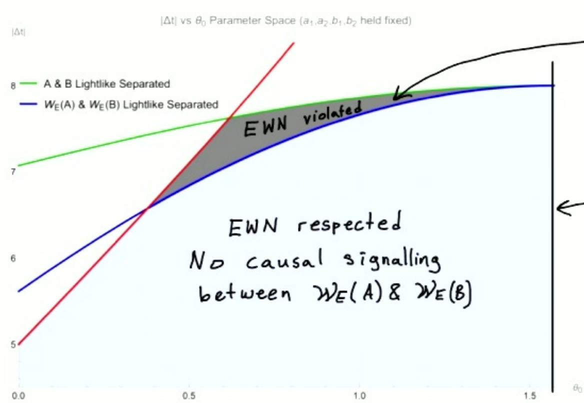
[Doi-Ogawa-KS-Suzuki-Takayanagi 2024]

Constraints from EWN for Holography at a Finite Cutoff

By: Krishan Saraswat



Q: For what $|\Delta t| = |t_b - t_a|$ is EWN violated?



Causal signalling between $\mathcal{W}_E(A)$ & $\mathcal{W}_E(B)$
(Enhanced non-local correlations between A & B)

$\theta_0 = \frac{\pi}{2}$ when cutoff/brane coincides with boundary
$\mathcal{W}_E(A)$ & $\mathcal{W}_E(B)$ spacelike sep. $\Longleftrightarrow$ A & B spaclike sep.

On the Role of Area Metrics in Holography

Lavish Chawla, Aranya Bhattacharya, and Mario Flory

Jagiellonian University in Kraków, Poland

Is area more fundamental than length in (quantum) gravity?
Black Hole Entropy, Holographic Entanglement Entropy, Nambu-Goto Action in String Theory, Loop Quantum Gravity, ... hint towards this direction.

Area metrics fundamentally define area elements without relying on the notion of length:

$$dA^2 = \boldsymbol{G}_{\mu\nu\rho\sigma}(dx^\mu \wedge dx^\nu)\cdot(dx^\rho \wedge dx^\sigma), \qquad A[\Sigma] = \int_\Sigma dA\,.$$

Our Approach and Results:

- In the framework of AdS/CFT, we study linearized area metric fluctuations around an empty AdS_4 background.
- First principles: Entanglement first law in boundary CFT, Ryu-Takayanagi formula in area metric bulk.
- Outcomes:
- Holographic dictionary for boundary energy momentum tensor in terms of length and area metric perturbations.
- Generalized linearized Einstein's equations to include area metric degrees of freedom (no length metric analogue).

QIQG 2025

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On Infinite Tensor Networks, Complementary Recovery and Type II Factors

Wissam Chemissany Elliott Gesteau Alexander Jahn Daniel Murphy Leo Shaposhnik

We construct a toy framework that allows to think about the following questions:

What does it mean for a tensor network to be infinitely large?

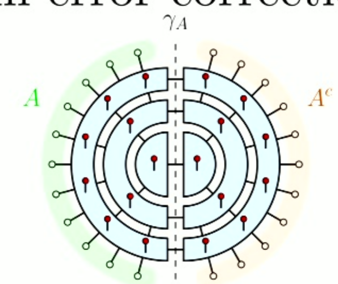
How can we recover the UV, knowing the IR and the RG map?

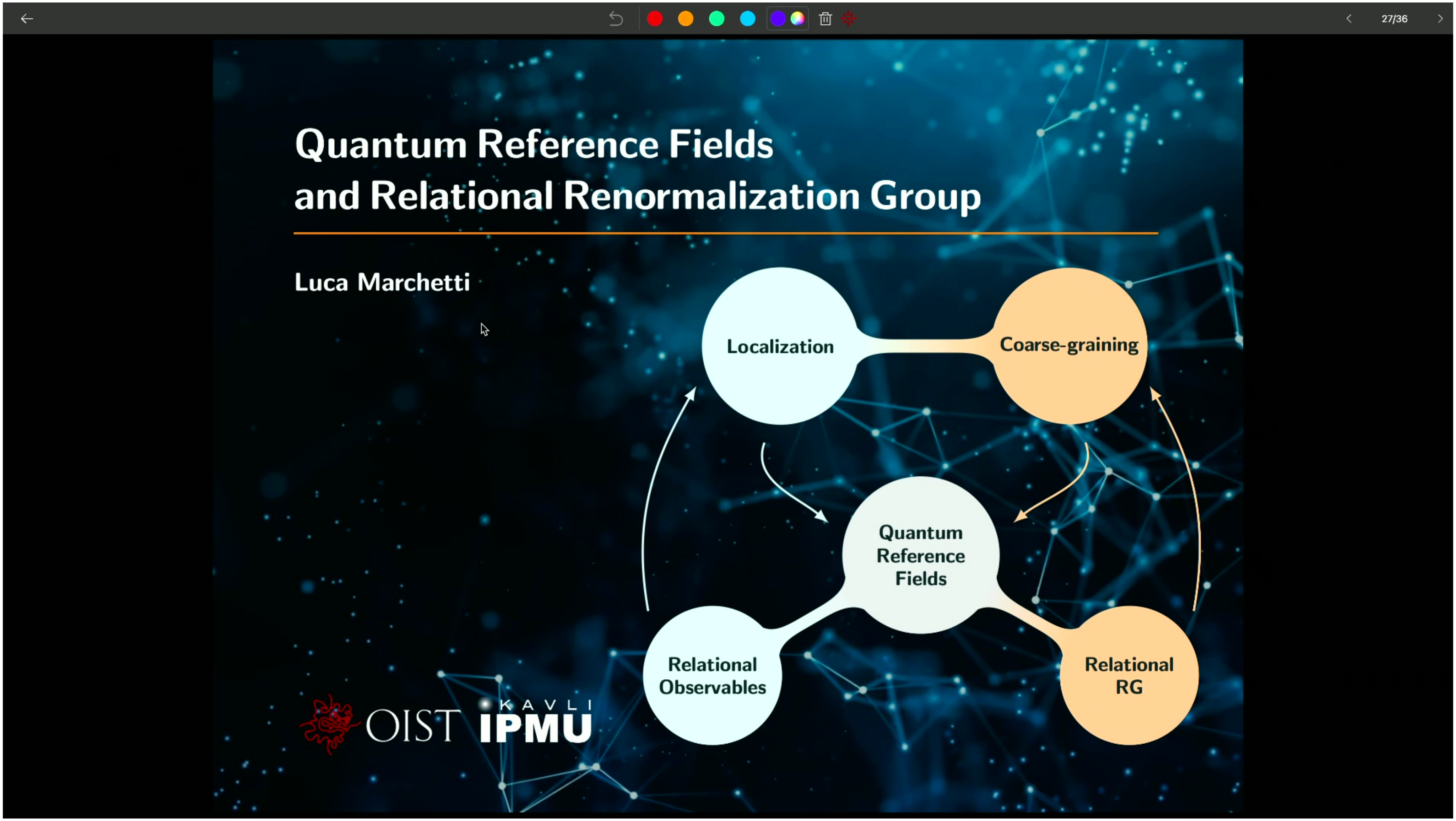
In what sense is RG flow a quantum error correcting code?

What tensor networks give rise to QFT's in the limit of infinite size?

What are the operator algebras of infinitely large tensor networks?

How does holographic quantum error correction help with all of that?

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Quantum Reference Fields
and Relational Renormalization Group
Luca Marchetti
Localization
Coarse-graining
Quantum Reference Fields
Relational Observables
Relational RG
OIST
KAVLI
IPMU

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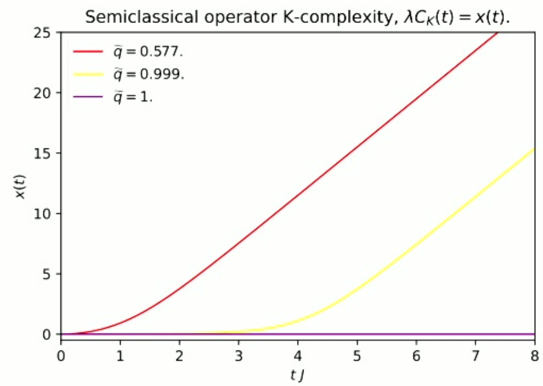
Operator K-Complexity in DSSYK and its bulk dual

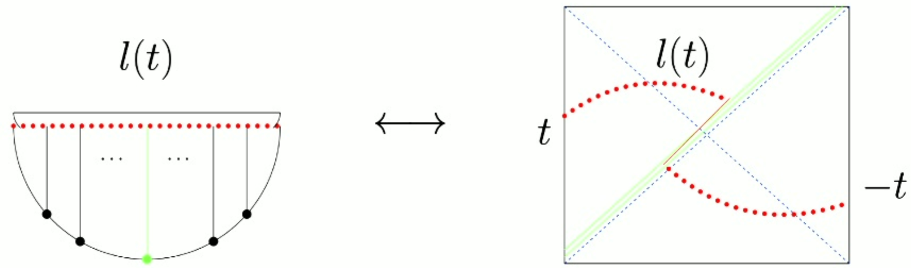
Marco Ambrosini (U. of Geneva), with E. Rabinovici, A. Sánchez-Garrido, R. Shir and J. Sonner

Operator complexity in semiclass. limit:

$$C_K(t) = \frac{2}{\lambda}\log(1 + (1-\tilde{q})\sinh^2 Jt)$$



In a triple-scaled limit, DSSYK+operator is dual to JT gravity+shockwave:



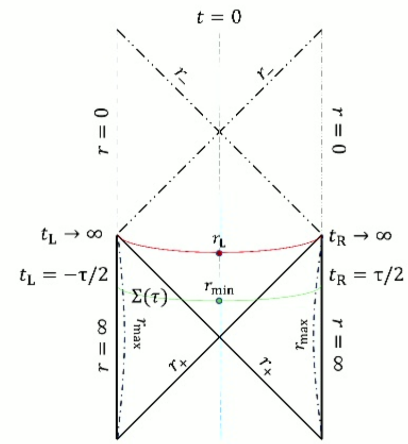
$$\Delta = \frac{E}{M}$$

Generalized Holographic Complexity of Rotating Black Holes

Authors: **Ming Zhang**, Jialong Sun, Robert B. Mann
Published: JHEP 09 (2024) 050

Key Points:

- Investigate generalized holographic complexity for odd-dimensional Myers-Perry AdS black holes with equal angular momenta.
- Demonstrate linear growth of complexity at late times, consistent with holographic duality.
- Identify novel early-time phase transitions (first-order, second-order, multicritical) due to black hole rotation.
- Propose a Maxwell-like area law to determine phase transition points.
- Find complexity of formation scales with thermodynamic volume for large near-extremal black holes.



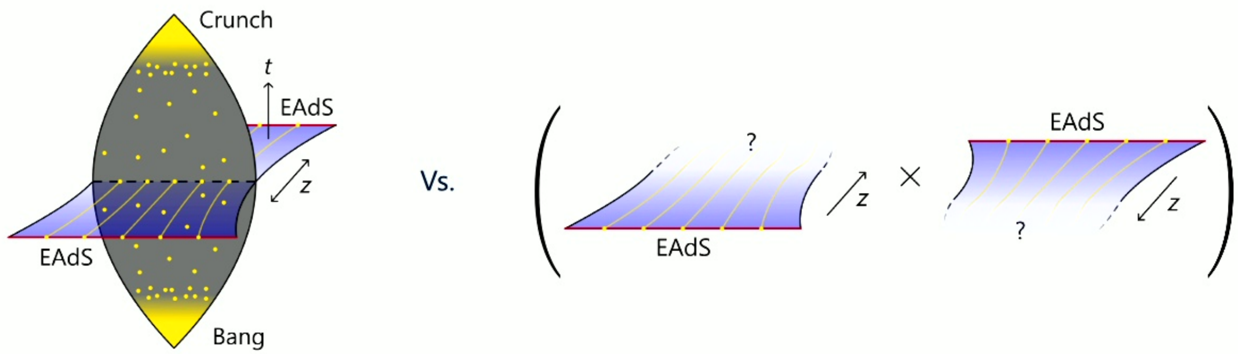
Penrose diagram of MP-AdS black hole, showing extremal hypersurface $\Sigma(\tau)$.

Renormalisation group flows from dusty wormholes

Pompey Leung, Mark Van Raamsdonk

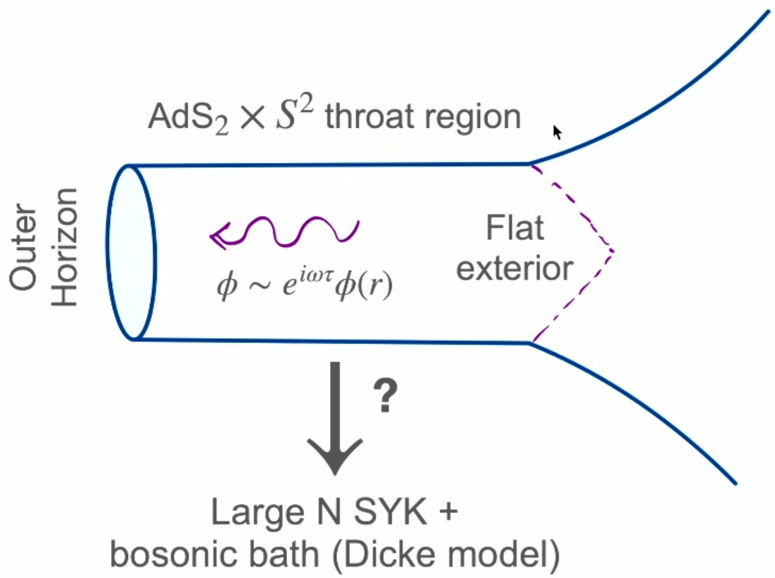
- Two-sided Euclidean AdS wormholes are interesting as they analytically continue to closed, big-bang/big-crunch cosmologies
- These homogeneous and isotropic wormholes can be supported by an inhomogeneous configuration of scalar fields. No exotic matter needed!
- On the other hand, the *competing saddle* in the two-boundary gravitational path integral are two copies of the disconnected, one-sided geometry

Q: What is the holographic interpretation of the one-sided, dusty bulk geometry as an RG flow?



Looking for a Microscopic Model for Black Hole Superradiance

Rana Zibakhsh



- Superradiance in the Dicke model is a phase in which enhanced coherent emission of photos by atoms is occurred.
- In charged black holes it is the amplification of scalar field through energy/charge extraction for $\omega < q\Phi_H$

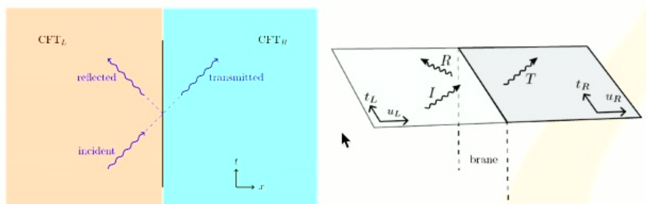
How do we identify the superradiance modes on both sides?

Are the QNMs in the upper half plane (unstable)?

Transport across higher dimensional interfaces

Sebastian Waeber - Ben-Gurion University of the Negev

Scattering at higher $d > 2$ interfaces



- Solve for basis of bulk solutions with IS-matching conditions

$$[\gamma_{ab}] = 0$$
$$[K_{ab}] - \gamma_{ab}[K] = -8\pi G \sigma \gamma_{ab}.$$

and undeformed boundaries.

- Construct asympt. outgoing wave in CFT_R

General bulk solutions are

$$ds^2 = ds^2_{empty\ AdS} + \frac{\epsilon e^{-i\omega t}}{\sin(\theta)^2} h_{\mu\nu}(z,\theta)\, dx^\mu dx^\nu$$

$$h = \sum_k f(k) B^k(z)(c_1^k P^k(\theta) + c_2^k Q^k(\theta)).$$

θ - angle of AdS_d slice, z radial coordinate on constant θ slices.

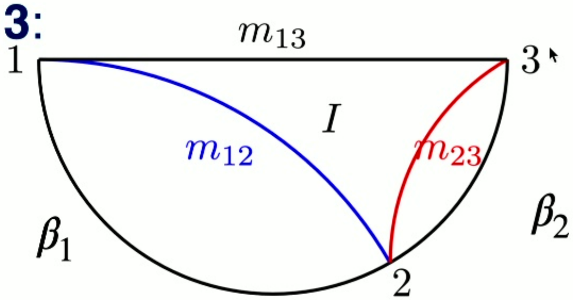
- IS matching and boundary conditions fix $\lim_{n\to\infty} k(n) = \alpha\, n + \beta$ and fix $c_{1,2}^{k,L}$ in terms of $c_{1,2}^{k,R}$
- Build planar waves at large u with e.g.

$$\sum_n t^{k(n)} J_{k(n)}(u) = \frac{e^{(t-1/t)u}}{2\alpha} + \mathcal{O}(1/\sqrt{u})$$

Geometry of Chord Intertwiner, Multiple Shocks and Switchback in Double-Scaled SYK

Forthcoming work by Sergio Ernesto Aguilar Gurtierrez (OIST) and Jiuci Xu (UCSB)

Chord intertwiner: The wavefunctions associated to segment **1 to 2** and **2 to 3** create **1 to 3**:



$$\phi_{\beta_1+\beta_2}(m_{13}) = \sum_{m_{12},m_{23}=0}^{\infty} \phi_{\beta_1}(m_{12})\,\phi_{\beta_2}(m_{23})\,I_{m_{12},m_{23},m_{13}}\ .$$

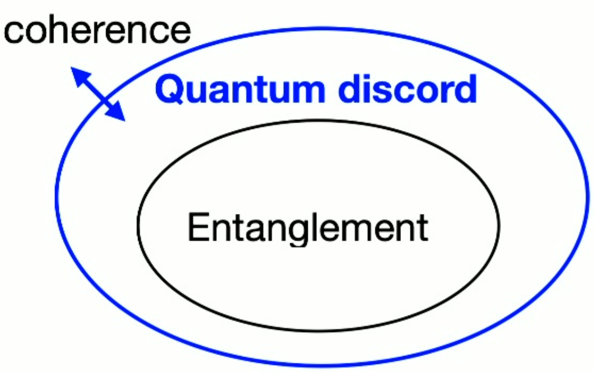
This simplifies boundary correlation functions describing **multiple shockwaves** in the bulk.
We find a microscopic observable (Krylov complexity) satisfying the **switchback effect** due
Operators inserted at times t_i with respect to the asymptotic boundary times t_L and t_R:

$$\mathcal{C} \propto |t_L - t_1| + |t_1 - t_2| + \ldots |t_m - t_R| - 2m\ t_{\text{scrambling}} + \mathcal{O}(1)\ .$$

Quantum correlation beyond entanglement: Holographic discord and multipartite generalizations

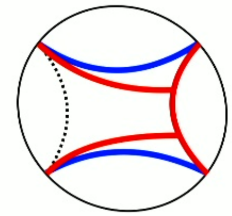
[2506.02131]

Takato Mori (Rikkyo University)



- Bulk dual

$$D_W(A\,|\,B) = S_B - S_{AB} + E_W(A:C)$$



- Non-entanglement quantum correlation

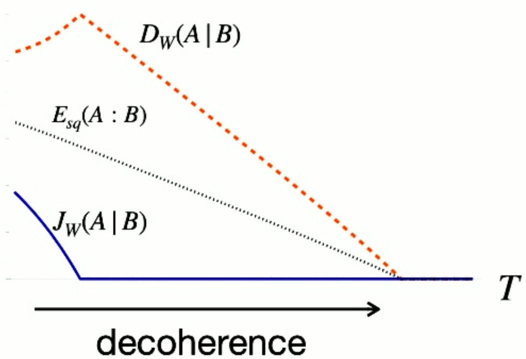
$$D_W > E_{sq} \Rightarrow \Delta Q_W(A\,|\,B) = \frac{h(A:C)}{2} > 0$$

Markov gap

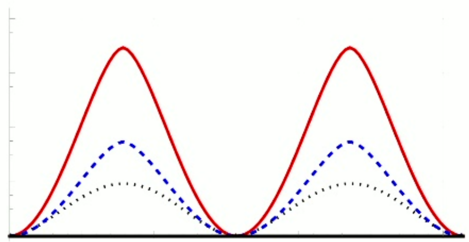
$$= E_{sq}(A:B) - E_D(A \leftarrow B)$$

one-way undistillable entanglement

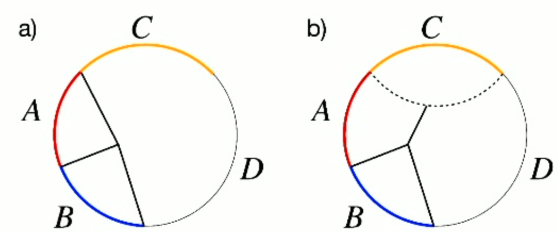
- Anti-decoherence effect with BH



- Boundary dual



- Multipartite generalizations



Check out my Friday talk (2:30 pm-) for my related works

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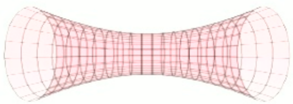
Are $S^1 \times S^2$ wormholes generic with large sources?

Xiaoyi Liu (UCSB)

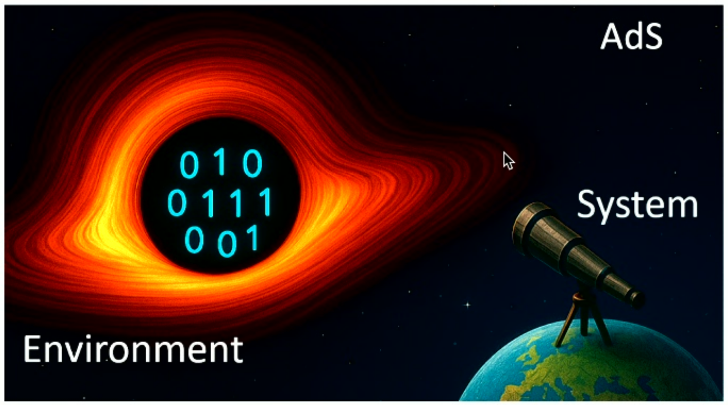
WIP with Don Marolf (UCSB) and Jorge E. Santos (Cambridge)

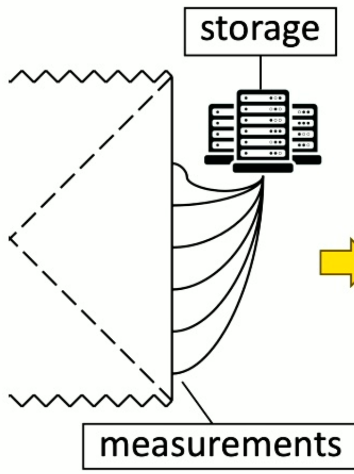


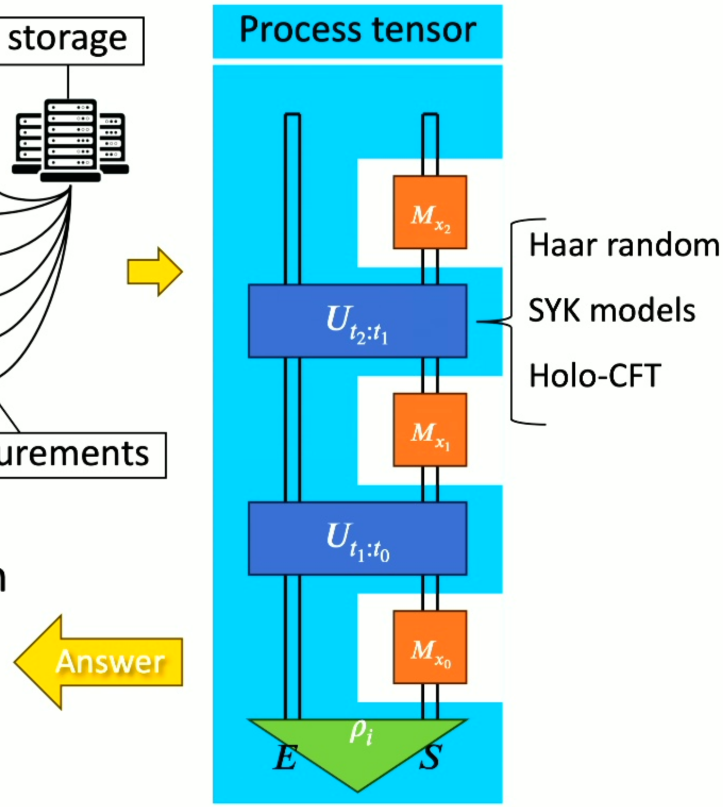
- Euclidean wormholes are important in explaining Hilbert space dimension of a black hole is finite.
- Wormholes should be generic in the presence of large Euclidean sources.
- We investigated this conjecture in a toy Einstein+scalar model in 4 spacetime dimensions.
- The answer to the question in title is **"no"** in our setting.
- Not necesserily bad! More investigation into more complicated models are needed and are more related.

Non-Markovianity in Chaotic Open Systems

-- Zhuo-Yu Xian







Q1: How long must a small detector measure radiation to determine a large black hole's quantum state?

Q2: When does the detector first detect non-Markovian effects from the black hole?