

Entanglement Through Topological Defects: Reconciling Theory with Numerics

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Physics 4 Future Colloquium

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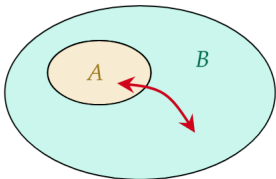
Based on **2512.07974** in collaboration with **Paolo Rossi**



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Entanglement

Non-local storage of information



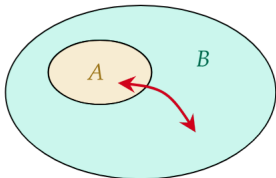
Spooky action at a distance!

That's quantum mechanics!



Entanglement

Non-local storage of information



Spooky action at a distance!

That's quantum mechanics!



Entanglement spectrum:

Eigenspectrum of Reduced density matrix ρ_A

Stores all information accessible through measurements on A , including info belonging to B

Captures topological features of full system

Rényi Entropies

System bipartition in (1+1)-dimensional critical systems

$$\mathcal{H} = \mathcal{H}_A \otimes \mathcal{H}_B$$



The entanglement entropies of a subsystem A

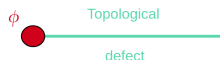
$$\rho_A = \text{Tr}_B[\rho] \in \mathcal{H}_A \quad S_A = -\text{Tr}_A[\rho_A \log \rho_A]$$

Rényi entropies

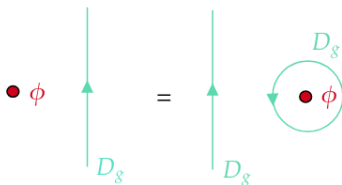
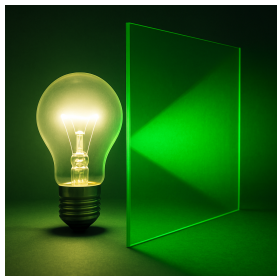
$$S_n = \frac{1}{1-n} \log \text{Tr}_A[\rho_A^n]$$

Twist Fields and Topological Defects

CFT of interest harbors **twist fields**.
Study in simpler setups first.

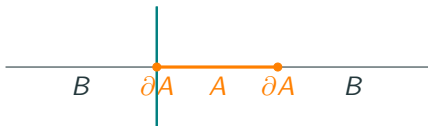
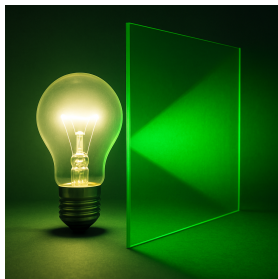


Topological defects implement **symmetries** and **dualities**

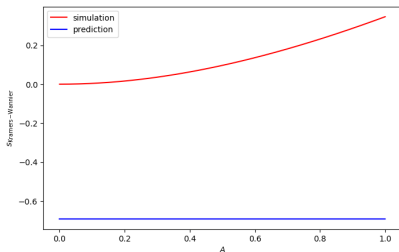


Naturally related to studying entanglement through topological defects.

Entanglement Through Topological Defects



$$S_n^D = \underbrace{\frac{c(n+1)}{6n} \log \frac{A}{\epsilon}}_{\text{universal}} + \underbrace{S_D}_{O(\epsilon)} + \dots$$

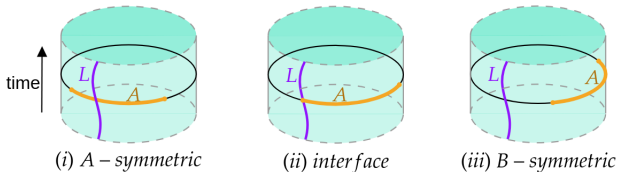


Theoretical predictions violated in
lattice simulations!!

Fix this!

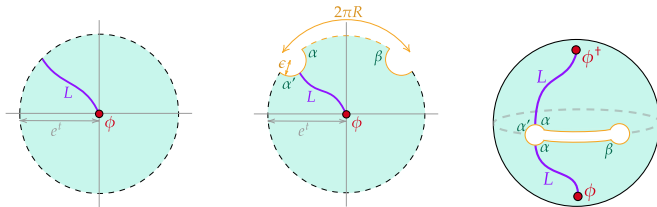
Importance of Defect Network Northe & Rossi, '25

Position of defect relative to interval matters!



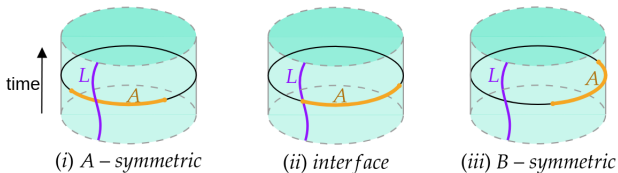
Defect network must be completed unambiguously!

Consider a zero temperature pure state: complete on sphere



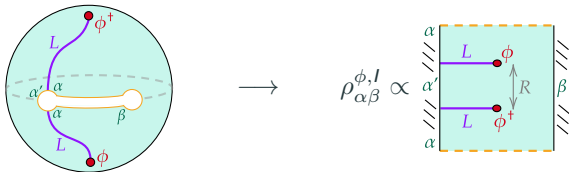
Defect Attached to Entangling Edge Northe & Rossi, '25

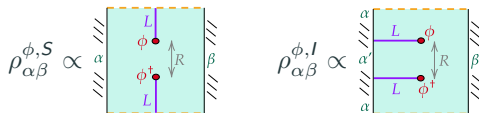
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Rényi entropy in presence of L : twisted sector excited state

$$S_n(\rho_{\alpha\beta}^{\phi,L}) = \frac{1+n}{n} \frac{c}{6} \log\left(\frac{\ell(R)}{\epsilon}\right) + \log[g_\alpha g_\beta \mathcal{F}_n^{\phi,L}(R)] + \dots$$

$\mathcal{F}_n^{\phi,L}(R)$ depends on h_ϕ, \bar{h}_ϕ and **defect network!**

We test this proposal for two defects in the Ising model and find agreement with simulations!

Conformal interfaces?

Other entanglement measures: relative entropy, entanglement negativity, reflected entropy, symmetry-resolved entanglement?

Holography and tensionless AdS/CFT? [Belin, Biswas, Sully '21](#), [Gaberdiel, Knighton, Vosmera '22](#), [Harris, Hikida, Schomerus, Tsuda, '25](#)