Title: PSI 2019/2020 - Quantum Matter Part 2 - Lecture 2

Speakers: Alioscia Hamma

Collection: PSI 2019/2020 - Quantum Matter (Part 2)

Date: February 12, 2020 - 10:00 AM

URL: http://pirsa.org/20020046

What is Quantum Complexity?
part 2

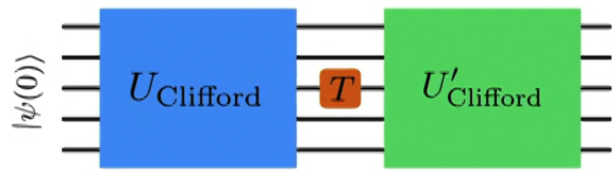
ALIOSCIA HAMMA

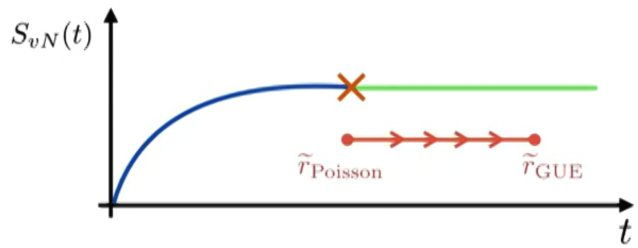
UMASS BOSTON

PSI - Quantum Matter

February 2020

Transition to Quantum Complexity by Doping with T gates

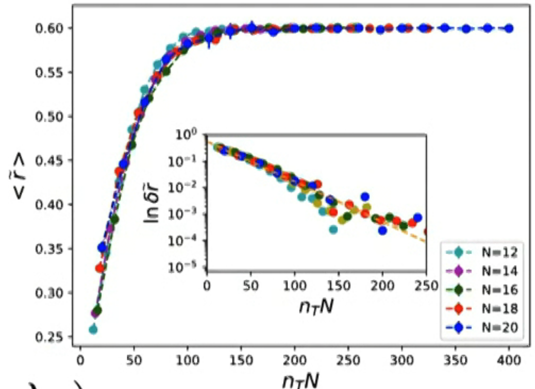




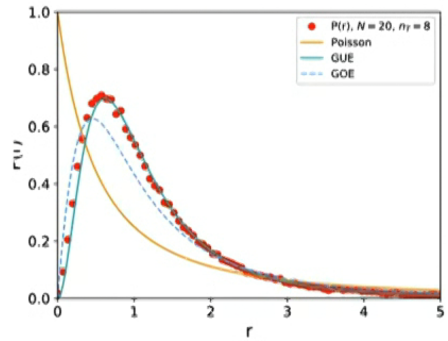
- We place n (possibly just one) T gates sandwiched by Clifford circuits
- n=0 will be just a Clifford circuit: ESS will be Poisson
- Can we drive a transition to Universal (GUE) ESS?
- Is integrability immediately destroyed?
- What does Universal GUE correspond to?

RESULTS

$$r_k = \frac{\lambda_{k-1} - \lambda_k}{\lambda_k - \lambda_{k+1}}$$

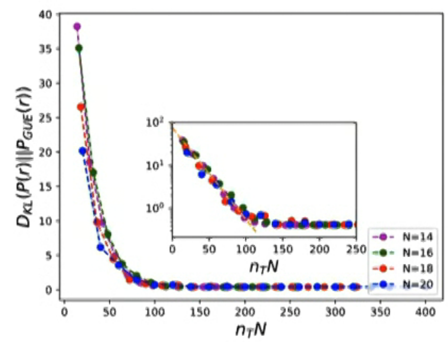


$$\tilde{r}_k = \frac{\min(\lambda_{k-1} - \lambda_k)}{\max(\lambda_k - \lambda_{k+1})}$$



(a)

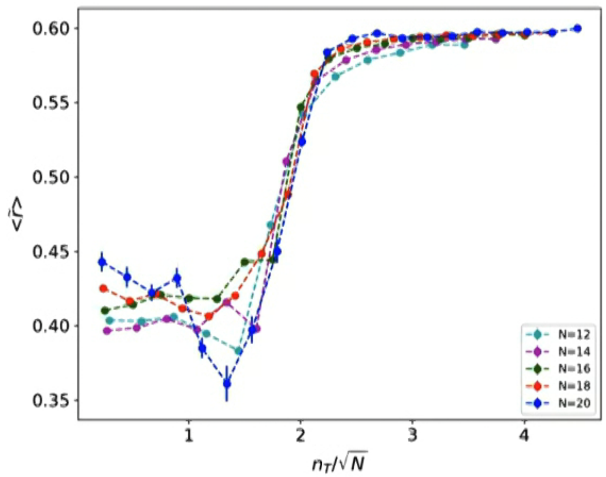
- A single T gate can drive to universal ESS
- Therefore irreversibility and unlearnability ensue
- Operator spreading and scrambling are involved
- the fate of T-designs and entanglement fluctuations depends on this transition



(b)

A Quantum KAM, the onset of quantum ch

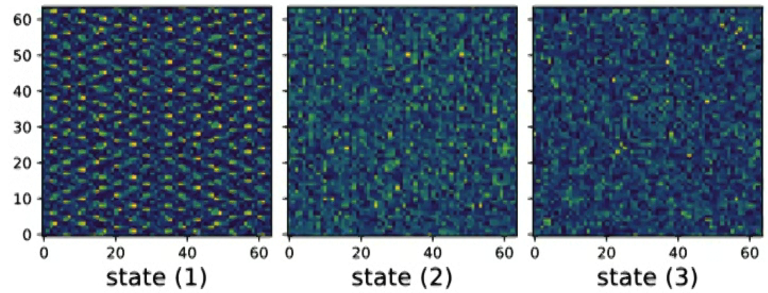
$$(T^\dagger)U_{\text{Clifford}}\,T\,U^\dagger_{\text{Clifford}}$$



- There is a threshold ~sqrt{N} before Clifford goes into chaos
- This quantity is akin to a OTOC

$$|\Psi\rangle = \sum_{x_A, x_B} \Psi(x_A, x_B)|x_A x_B\rangle$$

$$|\Psi(x_A, x_B)|^2$$



- 1) Clifford gates
- 2) Cliffort gates + Sqrt(N) T gates
- 3) Random unitaries

CLASSIFICATION BY MACHINE LEARNING

The 4−point out-of-time-order (OTO) correlation func
for the local operators V, W evolved by a RQC U is giv

$$\mathcal{F}_U(V,W) := \langle U^\dagger W^\dagger U V^\dagger U^\dagger W U V \rangle$$

$$W(t) = \sum_k^\infty \frac{(it)^k}{k!}[H, ...[H, W]...]$$

for $k \sim 2N/q$ we get 2^{2N} terms with similar non-negligible weight

For a chaotic circuit, the value of the $\mathcal{F}_U(V,W)$ reaches the value where $U^\dagger W U \mapsto \int dU U^\dagger W U$

Does the OTOC $\mathcal{F}_U(V,W)$ transitions from non-chaotic to chaotic behavior for a RQC doped by T gates? If yes, with what scaling n_T?

Out of Time-Order Correlators

- Black holes are efficient information scramblers
- Information initially localized will quickly thermalize and mix across the full system
- Fastest scrambling = random unitary evolution
- Chaotic dynamics => scrambling

SCRAMBLING AND BLACK HOLES

$$\frac{1}{K}\sum_j p_t(U_j) = \int dU p(U)$$

Unitary t-design

$$\Phi_t(\{U_j\}) = \frac{1}{K^2}\sum_{jk} |\langle U_j|U_k\rangle|^{2t}$$ Frame Potential

Φ_t is a t-design iff $\Phi_t = t!$

TRANSITION IN DESIGN

- When does the onset of complexity happen by universal gates? Is it sqrt{N}?
- What is the role of time fluctuations of the entropy in the effectiveness of cooling?
- When does the unlearnability transition happen?
- When does the transition to 4-designs happen?
- Can you dope anything to a 4-design?
- Can you dope Clifford to Universal by sqrt{N}?

QUESTIONS