Time-correlated noise & confinement phenomena in quantum computation
Quantum Memory

Isolation + Control
Quantum Memory

\[ T_c > 0 \]

Self-correction

\[ \text{Isolation + Control} \]
Quantum Memory

- Isolation + Control

- Self-correction
- Error correction
- Local noise
Quantum Memory

- Isolation + control

- Self-correction
- Error correction
- 

- Single-shot EC
- Spatially local noise

$T_c > 0$
Quantum Memory

- Isolation + control

- Passive
- Active

$T_c > 0$

Self-correction

Error correction

- Local noise

Inspire

Approach

Single-shot EC

- Spatially local noise

Gauge color codes

Lattice Gauge Theory

- $d = 3$
Quantum Memory

- Isolation + control

- Active
  - Self-correction
  
- Passive
  - Error correction
  - Local noise
  
- Single-shot EC
  - Spatially local noise
  
- Gauge color codes

- Lattice Gauge Theory
  - $d = 3$
Quantum error correction

logical qubit

physical qubits
Quantum error correction
Quantum error correction

ideal

noisy
Topological codes

local check operators

local indistinguishability
Topological codes

code = ground state
syndrome = excitations

\[ H = \sum \]
$d = 2$
$d = 2$
\[ d = 2 \]

\[ T_c = 0 \]
\( d = 4 \)

\[ T_c > 0 \]
Localized measurement errors yield localized residual noise
\[ P \left( 1 \leq x \leq 5 \right) \leq x^2 \]
\[
\Pr(\square \land \land \land 5) \leq \\
\Pr(1 \land 3) \leq \lambda^2
\]
Quantum memories based on single-shot error correction exhibit an error threshold under spatially local noise
Gauss

\[ e \]

\[ m \]

\[ z \]

\[ z \]
Subsystem codes

\[ H_0 = H_{\text{logical}} \otimes H_{\text{gauge}} \]

logical qubits      “gauge” qubits
Subsystem codes

\[ \mathcal{H}_0 = \mathcal{H}_{\text{logical}} \otimes \mathcal{H}_{\text{gauge}} \]

logical qubits \quad \text{“gauge” qubits}

Gauge color codes

gauge qubits = gauge field (lattice)

syndrome = sources

logical qubits = “hidden” topological d.o.f.
\[
\begin{bmatrix}
1 & 0 \\
0 & \sqrt{i}
\end{bmatrix}
\]

\[
\frac{1}{\sqrt{2}} \begin{bmatrix}
1 \\
1
\end{bmatrix}
\]

\[
d = 2
\]
• $d = 1$ is a clear-cut no-go for time correlated noise. What about $d = 2$?

• What are the physics of gauge codes? Gapless phases, confinement…

• What is the physics behind the computational power of color codes?