Quantum Darwinism is Generic

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Joint work with
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Classical from Quantum

How the classical world we perceive emerges from quantum mechanics?

*Decoherence*: lost of coherence due to interactions with environment
Classical from Quantum

How the classical world we perceive emerges from quantum mechanics?

**Decoherence**: lost of coherence due to interactions with environment

We only learn information about a quantum system indirectly by accessing a small part of its environment.

E.g. we see an object by observing a tiny fraction of its photon environment
Quantum Darwinism in a Nutshell

(Zurek ’02; Blume-Kohout, Poulin, Riedel, Zwolak, .....

**Objectivity of observables:** Observers accessing a quantum system by probing part of its environment can only learn about the measurement of a *preferred observable*
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\[ |\phi\rangle_{B_1,\ldots,B_k} := e^{-itH_{SE}} |\psi\rangle_{S} \otimes |0\rangle_{E} \]

\( \phi_{B_j} \) only contains information about the measurement of \( \{M_k\}_k \) on \( |\psi\rangle_{S} \)

And almost all \( B_j \) have close to full information about the outcome of the measurement \( \{M_k\}_k \)
Quantum Darwinism: Examples

(Riedel, Zurek ‘10) Dielectric sphere interacting with photon bath:
Proliferation of information about the position of the sphere

(Blume-Kohout, Zurek ‘07) Particle in brownian motion (bosonic bath):
Proliferation of information about position of the particle

Is quantum Darwinism a general feature of quantum mechanics?

No: Let $|\phi\rangle_{B_1,...,B_k} := e^{-itH_{SE}} |\psi\rangle_S \otimes |0\rangle_E$

For very mixing evolutions $U = e^{-itH}$, $\phi_{B_j}$ is almost maximally mixed
for $B_j$ as big as half total system size

Information is hidden     (again, QECC is an example)
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**Objectivity of Observables is Generic**

**thm** (B., Piani, Horodecki ‘13) For every $\Lambda : S \rightarrow B_1, \ldots, B_n$, there exists a measurement $\{M_k\}$ on $S$ such that for almost all $j$,

$$
\Lambda_j(\rho) := \text{tr}_{B_j} \circ \Lambda(\rho) \approx \sum_{j} \text{tr}(M_j \rho) \sigma_{j,k}
$$

$$
O(d_S^3 n^{-1/3})
$$

Proof by monogamy of entanglement and quantum information-theoretic techniques (blackboard)
Thanks!