

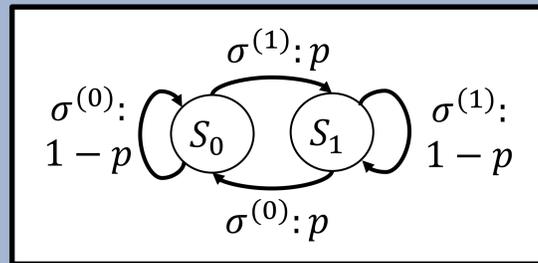
Work extraction from quantum systems with complex temporal correlations

Ruo Cheng Huang, Paul M Riechers, Mile Gu, Varun Narasimhachar



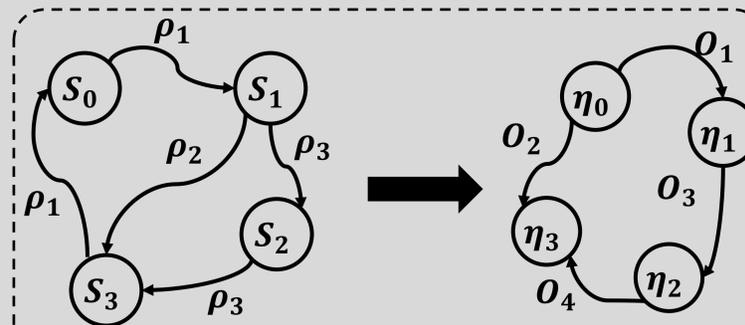
Aim

- Must be able to **adapt** protocol based on **past performance**



- Classical stochastic process
- $\{S_i\}_i$ are latent states
- $\sigma^{(x)}:p$ represent a transition occurring with probability, p , and emitting $\sigma^{(x)}$
- quantum state, $\sigma^{(x)}$ is emitted at each time step

Results



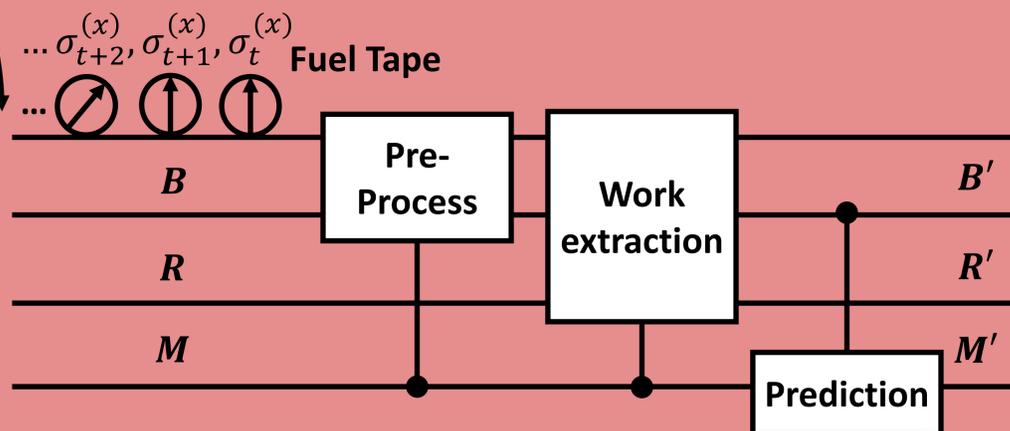
1. latent state dynamic $\{S_i\}_i \rightarrow$ meta-dynamic of state of knowledge $\{\eta_t\}_t$

Benchmarking

- **Memory-assisted Quantum** (represented by a sequence of three circles with arrows pointing right, where the first two have blue arrows and the last has a red arrow)
- Memory-assisted Classical (represented by a sequence of three circles with arrows pointing right, where the first two have blue arrows and the last has a red arrow, with a dashed red line connecting the first two)
- **Memoryless Quantum** (represented by a sequence of three circles with arrows pointing right, where the first two have blue arrows and the last has a red arrow, with a dashed blue line connecting the first two)

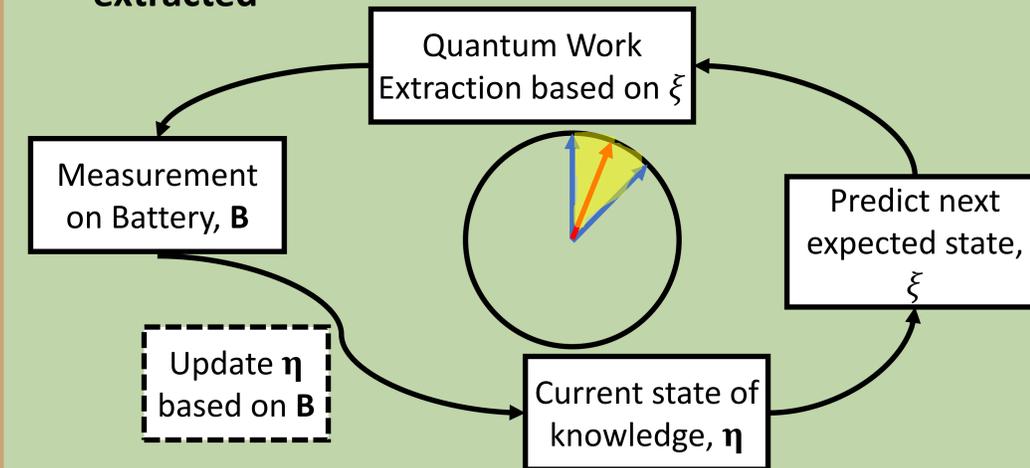
Construction of Engine

- **Fuel tape**, internal memory M , heat reservoir R , Battery, B , to be charged.
- M keeps track of *state of knowledge*, η_t [1]
- $\eta_t = \{\Pr(s_t = s_i)\}_{i \in |S|}$
- **Work extraction** (knowledge dependent) [2]
- **Pre-process**, rotation of state to eigenstate
- **Thermalization**, bring state to thermal state

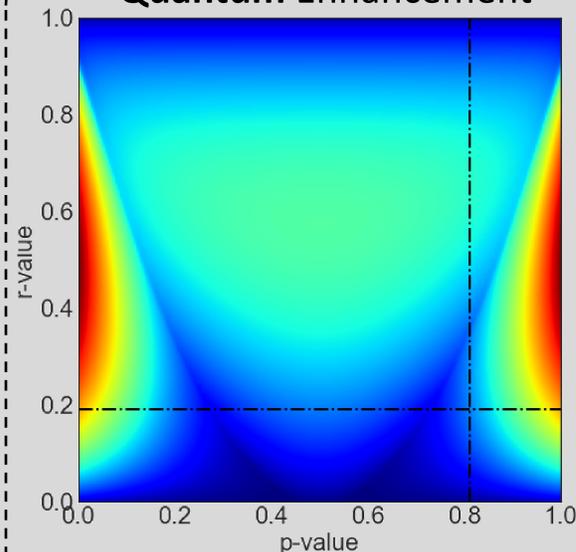


Operation of Engine

- Engine tailors extraction to expected state, ξ_t
- Measure B to obtain work value
- η_t is iteratively updated conditioned on **work extracted**

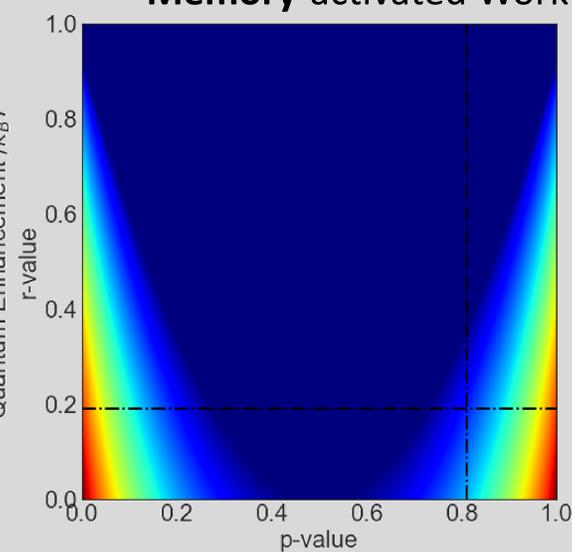


Quantum Enhancement



2. Quantum **always** outperform classical in the presence of coherence

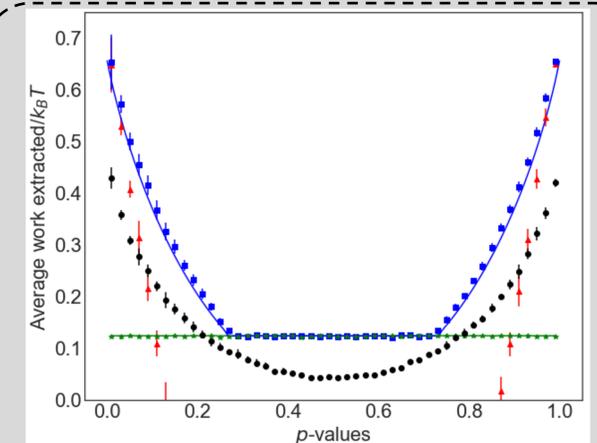
Memory-activated Work



3. Memory of past output is **not always** useful

$$r = \text{Fidelity}(\sigma^{(0)}, \sigma^{(1)})$$

1. Skrzypczyk, P., A.J. Short, and S. Popescu, *Work extraction and thermodynamics for individual quantum systems*. Nature communications, 2014. 5(1): p. 1-8.
 2. Crutchfield, J.P., *The calculi of emergence: computation, dynamics and induction*. Physica D: Nonlinear Phenomena, 1994. 75(1-3): p. 11-54.



4. Sharp **phase boundary** between area with and without memory-advantage

