How Does Nature Create a Bridge From Fragile Quanta to the Objective World of Everyday Experience?

Conor Ryan
MSc Quantum Science and Technology

Quantum Science and Technology

PAPER

Witnessing non-objectivity in the framework of strong quantum Darwinism

Thao P Le[1] and Alexandra Olaya-Castro[1]

Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom

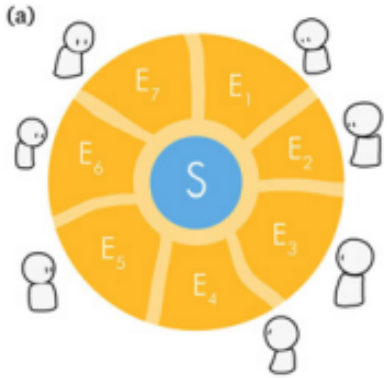
[1] Authors to whom any correspondence should be addressed.

The Problem

Definition

Objectivity: A quantum state is **objective** if it is

1. Simultaneously accessible to many observers
2. Observers can determine the state independently without perturbing it.
3. Observers arrive at the same result.



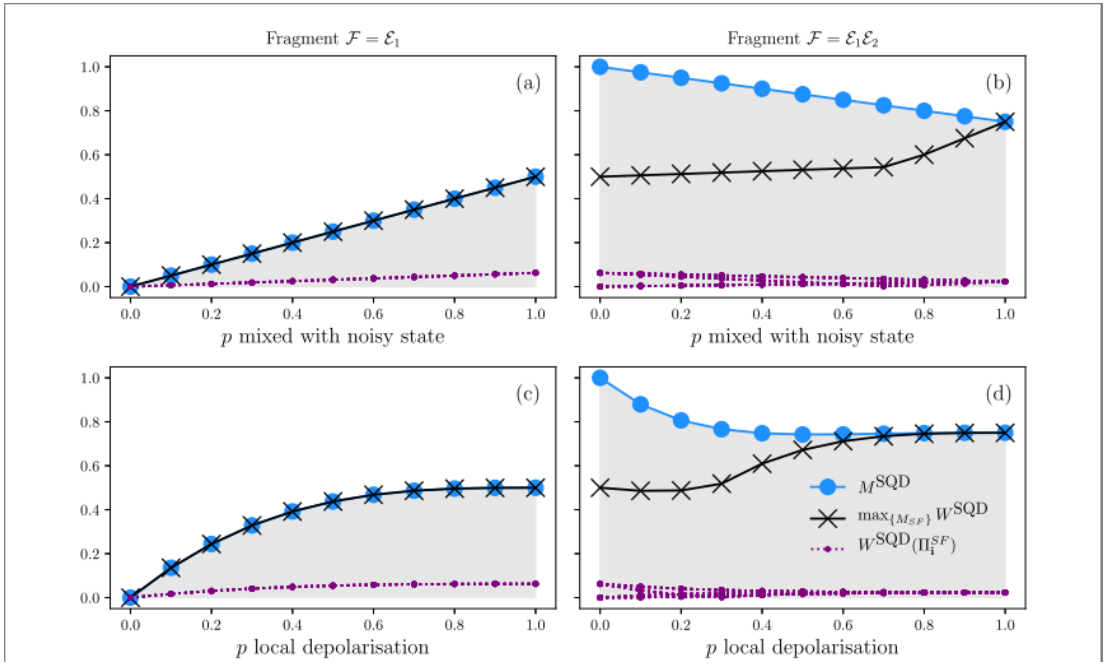
- The objectivity of a quantum state is important in understanding the quantum-to-classical transition.
- Current objectivity tests use quantum state tomography over the system and accessible environment, making scalability difficult.

The Idea

- Instead of using the quantum state tomography approach this work introduces a non-objectivity witness in the Strong Quantum Darwinism (SQD) framework.
- The witness test considers objectivity occurring in a preferred subspace and is measured by comparing the evolution of the system-environment state with and without the application of some objectivity enforcing operation.
- The goal is that this witness can detect objectivity in a system-environment state with less measurements than quantum state tomography.

The Task

The project aimed to reproduce the following figures.



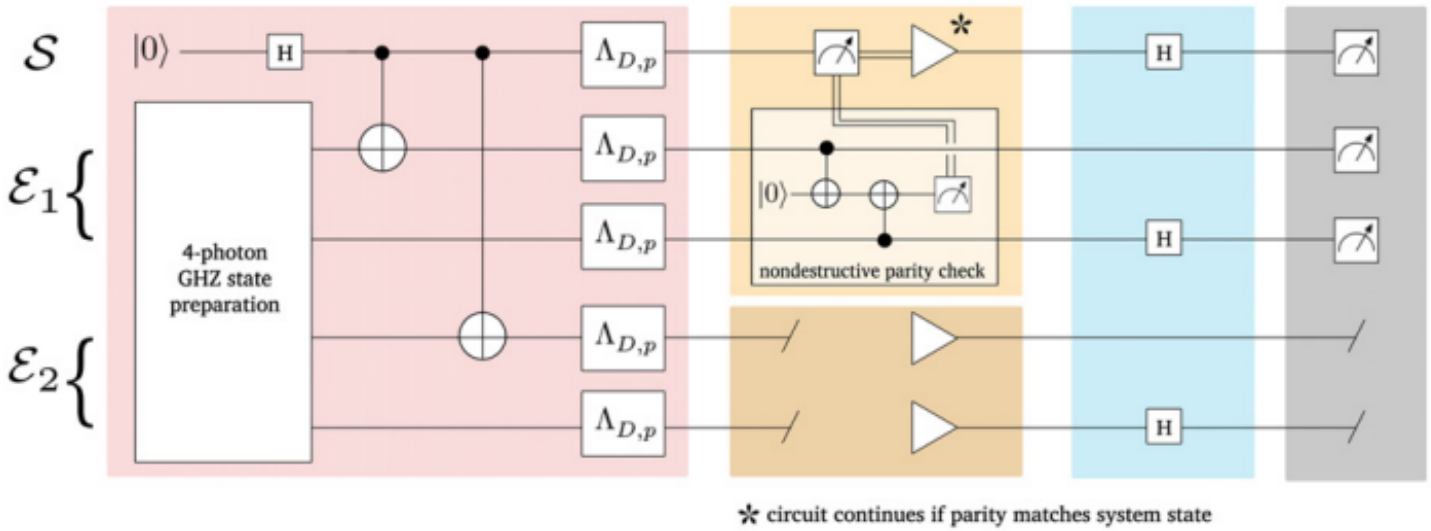
$$M^{SQD}\left(\rho_{\mathcal{SF}}(t)\right) = ||\rho_{\mathcal{SF}}(t) - \Gamma^{SQD}_{\mathcal{SF}}\left(\rho_{\mathcal{SF}}(t)\right)||_1 \tag{1}$$

$$\Gamma^{SQD}_{\mathcal{SF}}\left(\rho\right) = \sum_i \left(|i\rangle\langle i|_{\mathcal{S}} \otimes \Pi_{\mathcal{F}|i} \otimes \mathcal{I}_{\mathcal{E}\setminus\mathcal{F}}\right) \rho \left(|i\rangle\langle i|_{\mathcal{S}} \otimes \Pi_{\mathcal{F}|i} \otimes \mathcal{I}_{\mathcal{E}\setminus\mathcal{F}}\right) \tag{2}$$

$$W^{SQD}\left(M_{\mathcal{SE}}\right) = |P_{\mathcal{I}_{\mathcal{SF}}} - P_{\Gamma^{SQD}_{\mathcal{SF}}}| \tag{3}$$

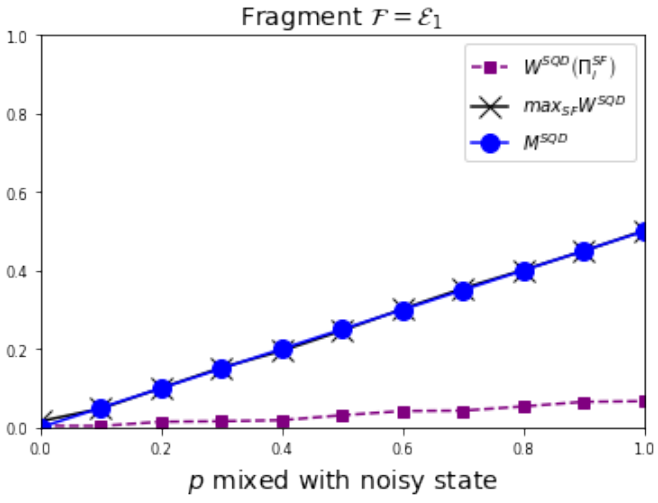
The Method

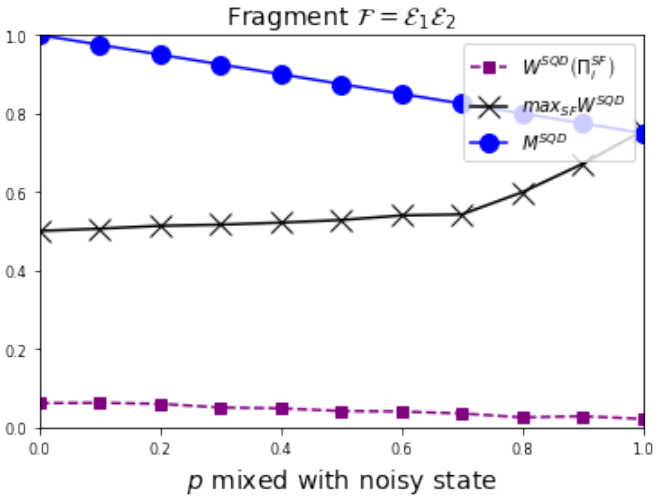
To calculate $P_{\mathcal{I}_{\mathcal{SF}}}$ and $P_{\Gamma_{\mathcal{SF}}^{SQD}}$ a quantum circuit was run with and without the objectivity operation, and measurements performed on the system-fragment qubits.
The following is an example of one of the circuits.

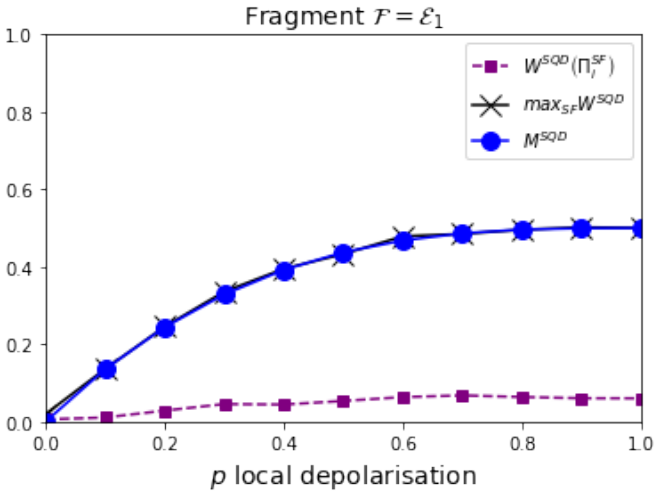


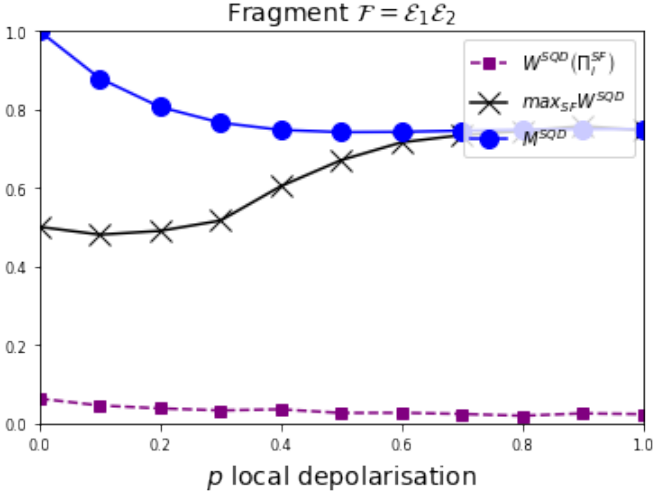
My Results

My results, produced using IBM's Quantum Software Development Kit Qiskit are seen in the following figures.









Successes and Improvements

- The results from the paper are clearly the same as the results produced in Qiskit.
- The code involved in producing the results did not make use of any specific Qiskit packages or features.
- The entire code can be run to produce all 4 plots in a few minutes, meaning it did not require a lot of computational resources.
- During the course of the project some methods which should have worked in theory were not working in practice and had to be replaced by different methods/code.