Discrepancies Between the Orthodox and Simultaneous Localization Interpretations of Quantum Mechanics

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INTRODUCTION

Quantum mechanics (QM) is the study of subatomic particles and a collection of theories which attempt to explain those particles' evolution and behavior. There exists a fundamental, unresolved debate in quantum mechanics on the question of measurement. The measurement of a quantum particle influences its behavior and causes an immediate "collapse" (or localization) of the particle's wave function. This means that observations "affect" the quantum world.

There is a measurement problem: why and how do impactful observations change a quantum system? Many solutions have been proposed for this "measurement problem" and are summarized in Figure 1 [1],[2],[3],[4],[5]. However, no solution (or "interpretation" of measurement) has been empirically proven to date.

With new advancements in quantum computing, simulations of a realistic quantum event can be run and corresponding measurements can be taken. A discrepancy between the Simultaneous Localization (SL) and Copenhagen ("orthodox") interpretations is exploited, which theoretically emerges 6-7 seconds after an initial measurement of a single-particle quantum state [6]. By comparing the predicted behavior of the SL and orthodox interpretations to a realistic quantum simulation, it can be determined which interpretation more accurately describes quantum theory in this specific case.

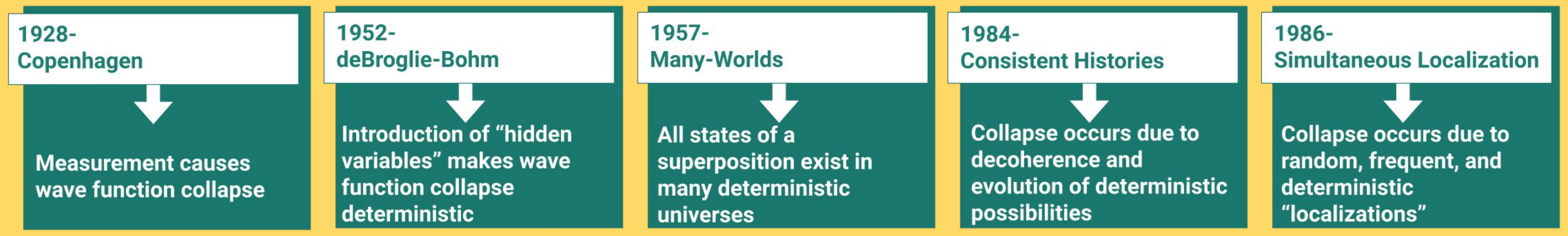

Figure 1: Timeline of the different interpretations of quantum measurement

ACKNOWLEDGEMENTS

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RESEARCH METHODOLOGIES

Discrepancy between the orthodox and SL interpretations occur in the state: $\sqrt{0.48}|0\rangle+\sqrt{0.52}|1\rangle$. According to SL, this state, if measured 6-7 seconds after an initial observation, should transform to $\sqrt{0.49}|0\rangle+\sqrt{0.51}|1\rangle$. The orthodox interpretation predicts the initial state should not change after being measured a second time.

1024 individual trials were conducted per data set. If the initial state does not vary after the second measurement, ~532.48 qubits should be measured in the $|0\rangle$ state.

If the second measurement reveals substantial deviance from this amount of $|0\rangle$ states, the phenomenon predicted by SL emerges.

The time waited is tested between the initial and repeated measurement at 0, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, and 9 seconds through a simulation on an IBM Q Experience computer [7].

CONCLUSIONS AND ANALYSIS

The control was found to approximately match the original state for both the initial and reapeated measurements, allowing a difference in variance from 532.48 between the first and second measurements of 4.42-48.625 for the orthodox interpretation to stand.

Larger variation differences were seen between measurements at 4.5 and 8 sec wait times instead of the 6-7 sec prediction.

Although a theoretical analysis of SL contradicts the empirical analysis on *where* the discrepancy occurs (depending on the range of wait time), the emergence of deviance from the initial state suggests SL may describe quantum behavior more accurately in this specific scenario.

EXPERIMENTAL LIMITATIONS

There are limitations on quantum simulator technology (such as significant quantum noise) that affect the adequacy of these results.

DATA AND FINDINGS

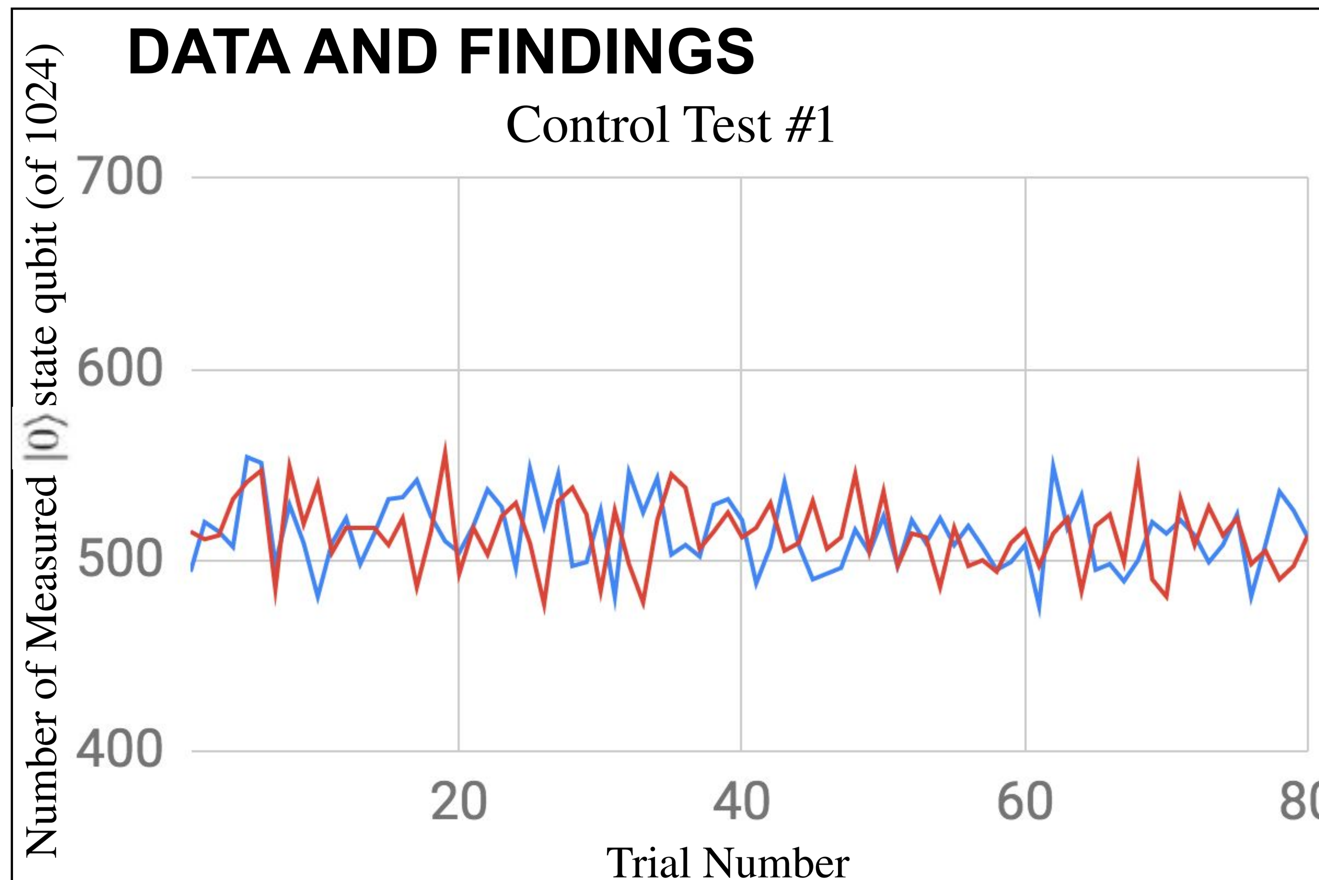

Figure 2: Out of 1024 measurements, comparisons of first (red) and repeated measurements (blue) in control test

Figure 3: Comparisons of first and repeated measurements with 3 seconds of wait time

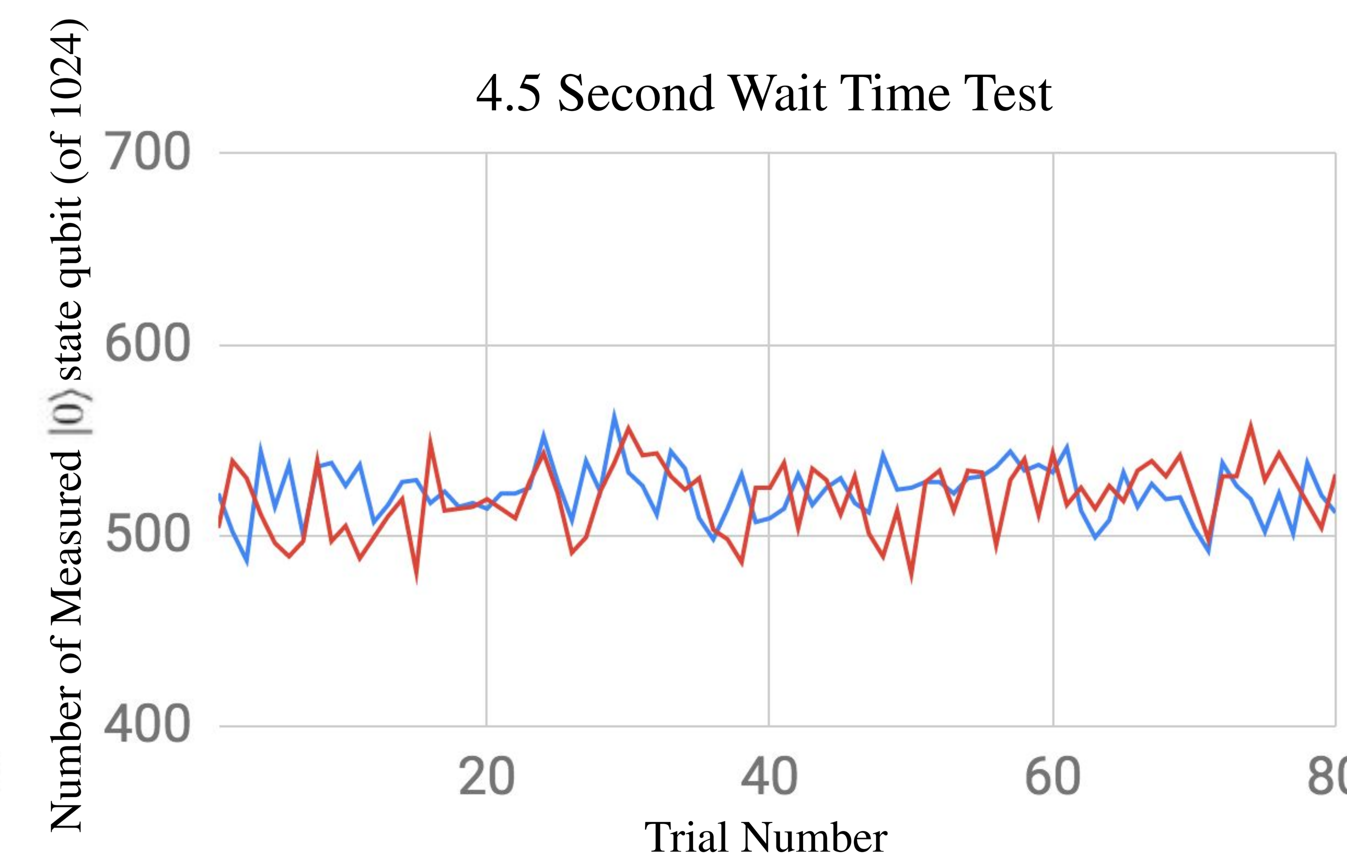

Figure 4: Comparisons of first and repeated measurements with 4.5 seconds of wait time

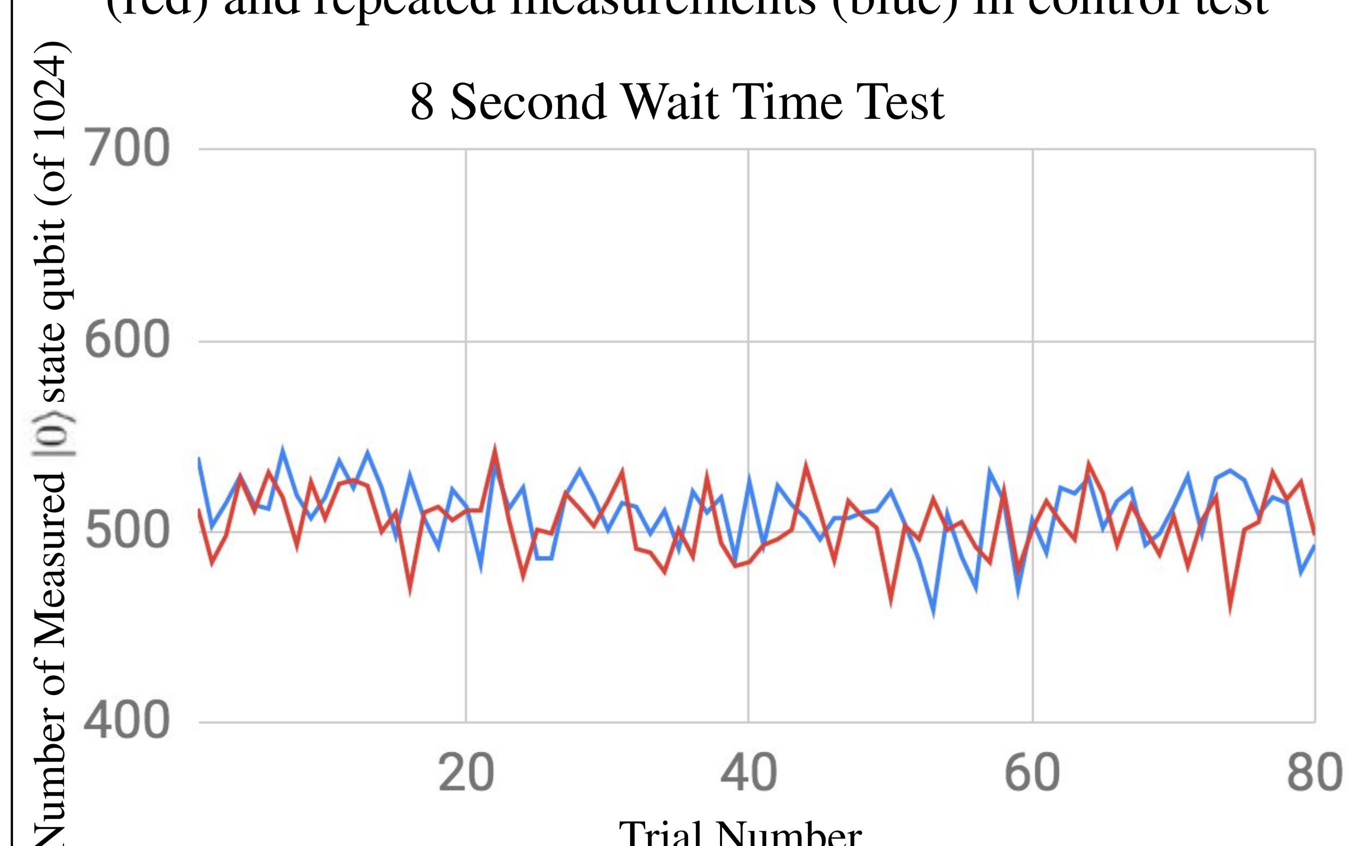

Figure 5: Comparisons of first and repeated measurements with 8 seconds of wait time

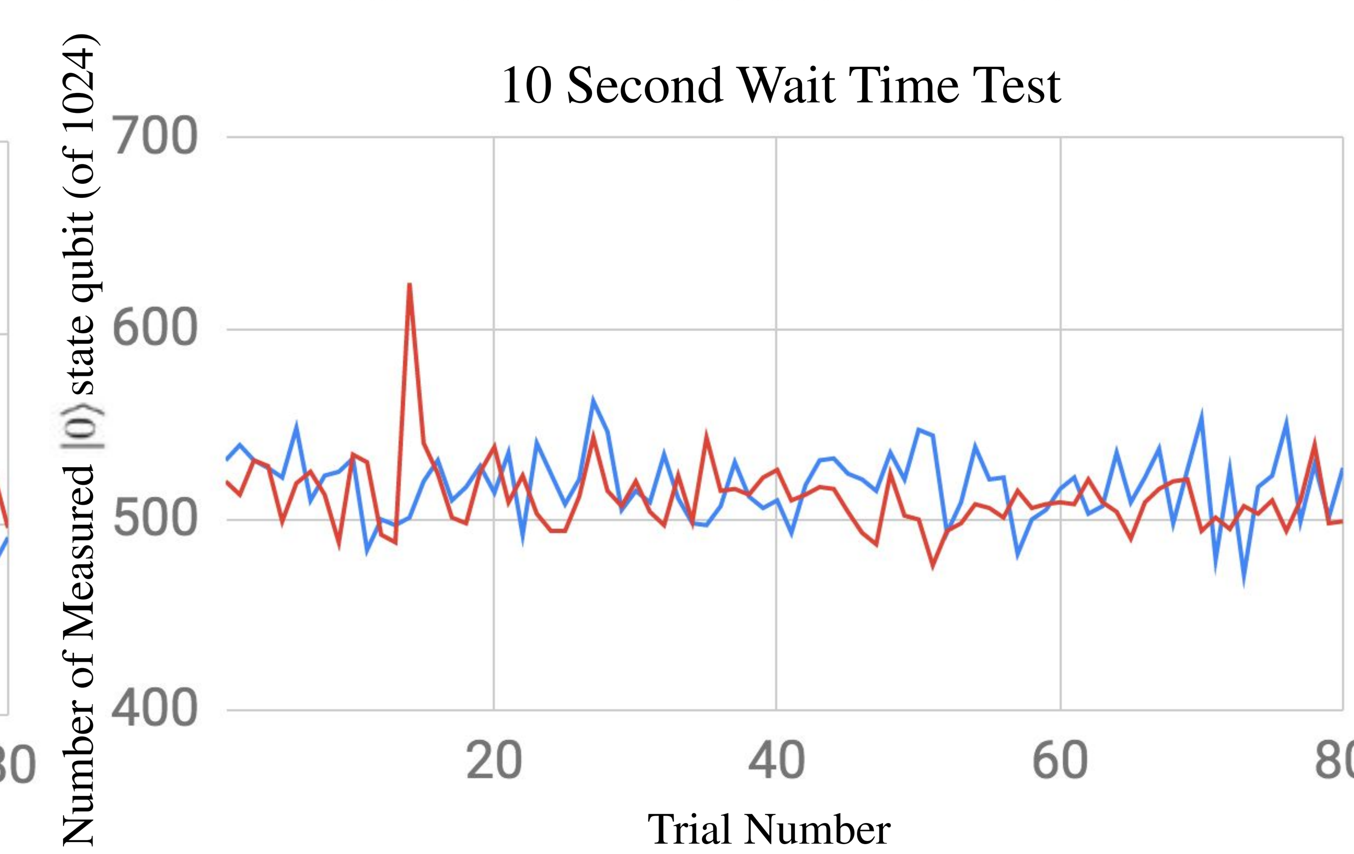

Figure 6: Comparisons of first and repeated measurements with 10 seconds of wait time

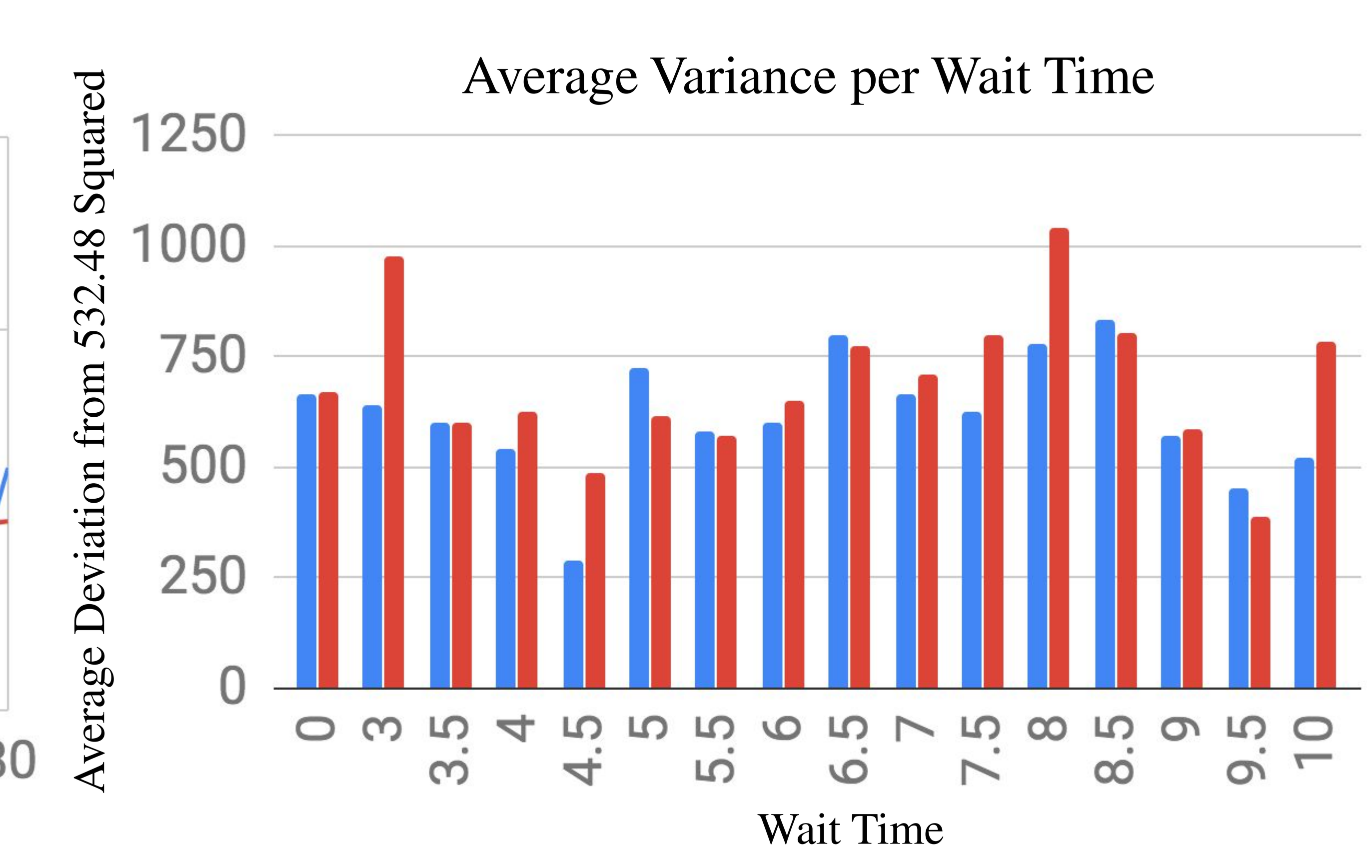

Figure 7: Average deviation from 532.48 for initial and repeated measurements over all tested wait times