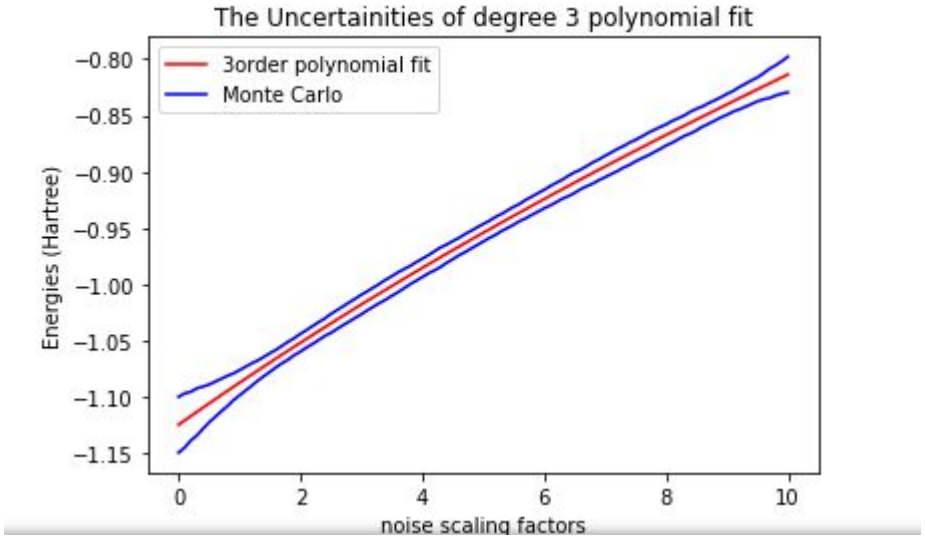
Statistical Analysis + Twirling VQE

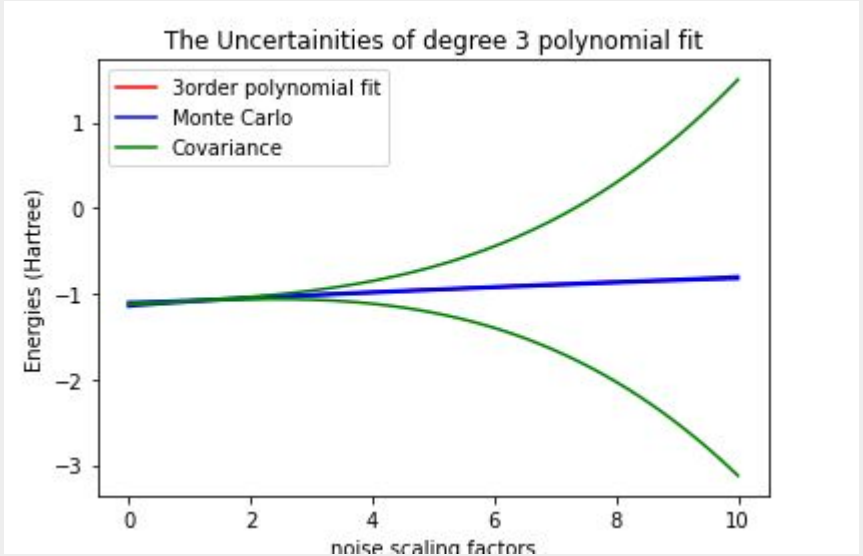
Meeting with Prof. Schnetzer, Prof. Hillery and Rikab
July 7, 2020

Update on Statistical Analysis

Comparing the Monte Carlo and the covariance methods of calculating uncertainties

- Having plotted the error curves, monte carlo is behaving as expected but covariance method is not.
- Numpy and Scipy give the same covariance matrices for the polynomial fits; nothing seems wrong with the matrices
- Verified uncertainties of first degree polynomial using covariance method by hand; code seems to work


The Uncertainities of degree 3 polynomial fit
3order polynomial fit
Monte Carlo
Energies (Hartree)
noise scaling factors


The Uncertainities of degree 3 polynomial fit
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Uncertainties vs Orders

The pattern found earlier - uncertainty of zero energy by Richardson being similar to that by polynomial with 0 degrees of freedom - is **consistent** across various orders.

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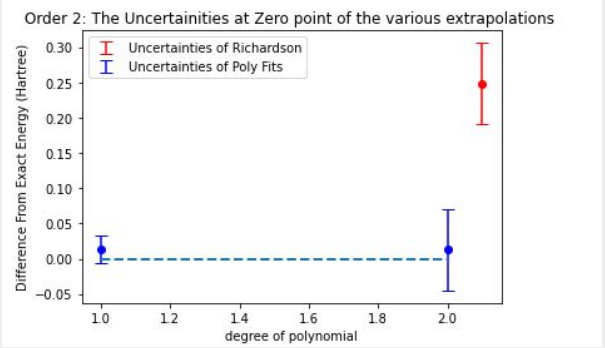
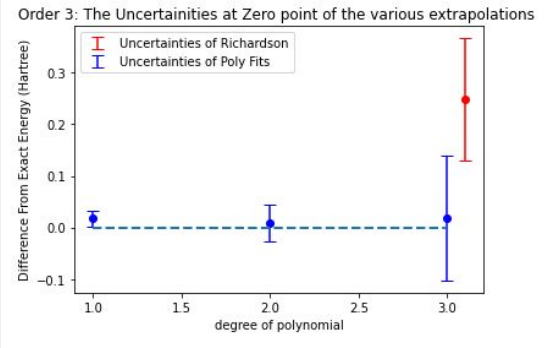
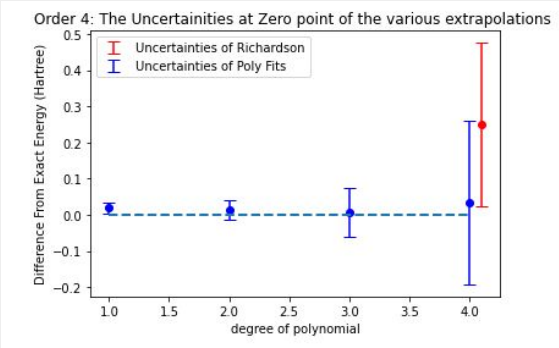
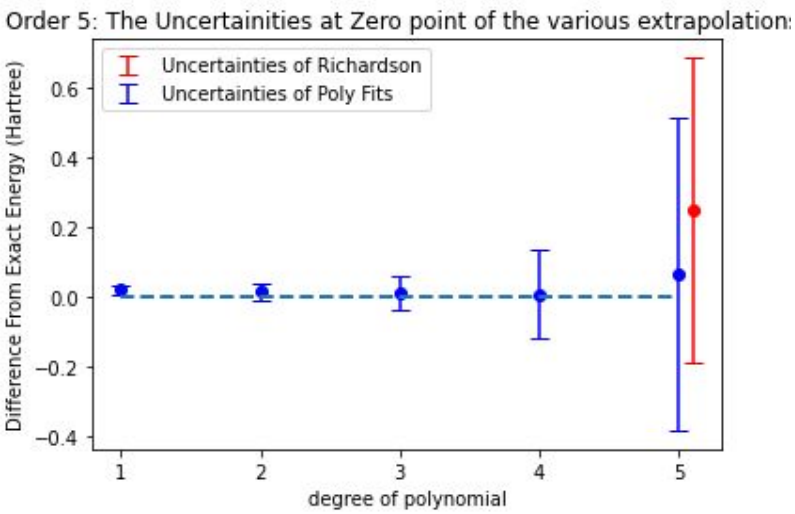
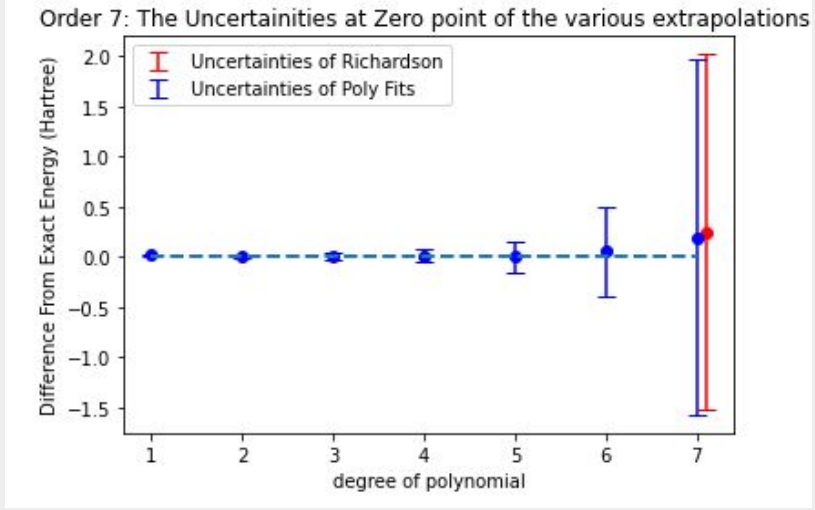
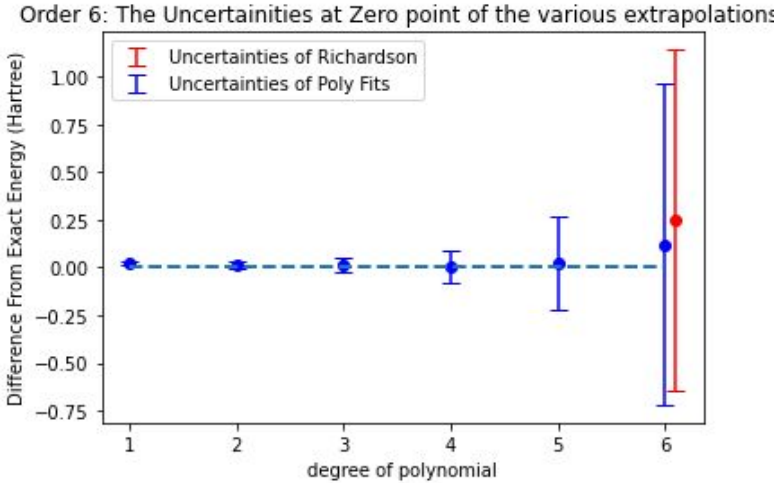


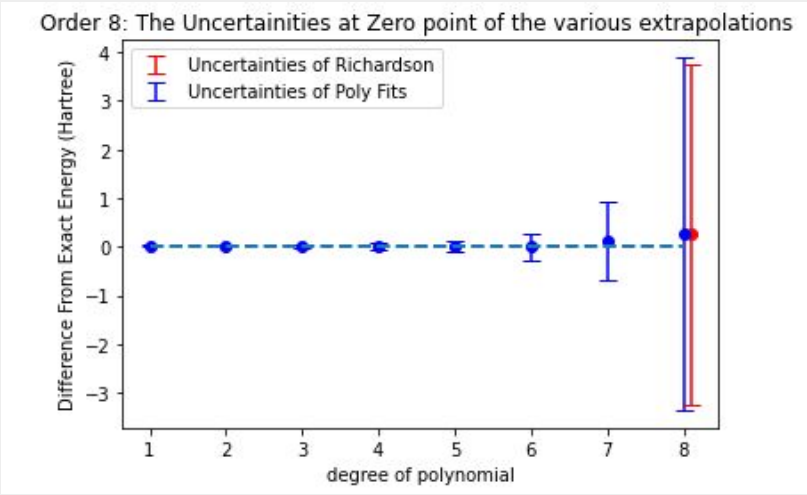





Order 5: The Uncertainities at Zero point of the various extrapolations
Uncertainties of Richardson
Uncertainties of Poly Fits
Difference From Exact Energy (Hartree)
degree of polynomial


Order 7: The Uncertainities at Zero point of the various extrapolations
Uncertainties of Richardson
Uncertainties of Poly Fits
Difference From Exact Energy (Hartree)
degree of polynomial


Order 6: The Uncertainities at Zero point of the various extrapolations
Uncertainties of Richardson
Uncertainties of Poly Fits
Difference From Exact Energy (Hartree)
degree of polynomial

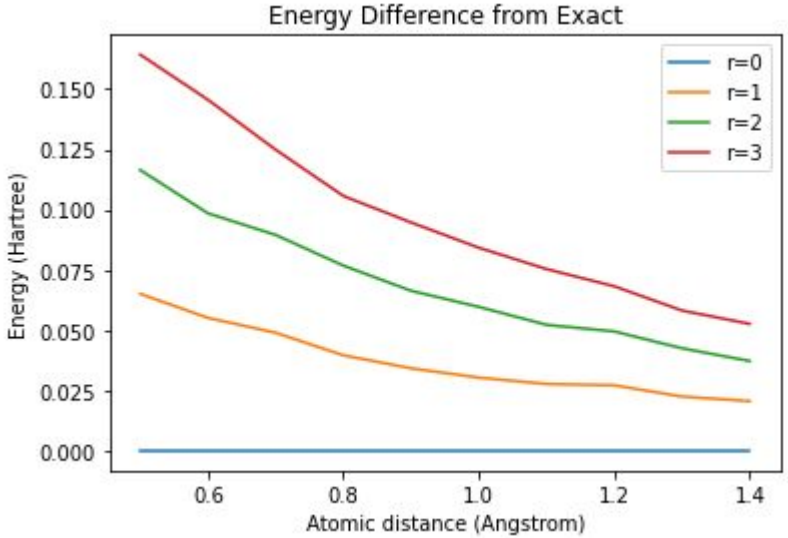

Order 8: The Uncertainities at Zero point of the various extrapolations
Uncertainties of Richardson
Uncertainties of Poly Fits
Difference From Exact Energy (Hartree)
degree of polynomial

Twirling + Error Simulation in VQE

As of now, the technique is not working in producing noise amplified results for H2

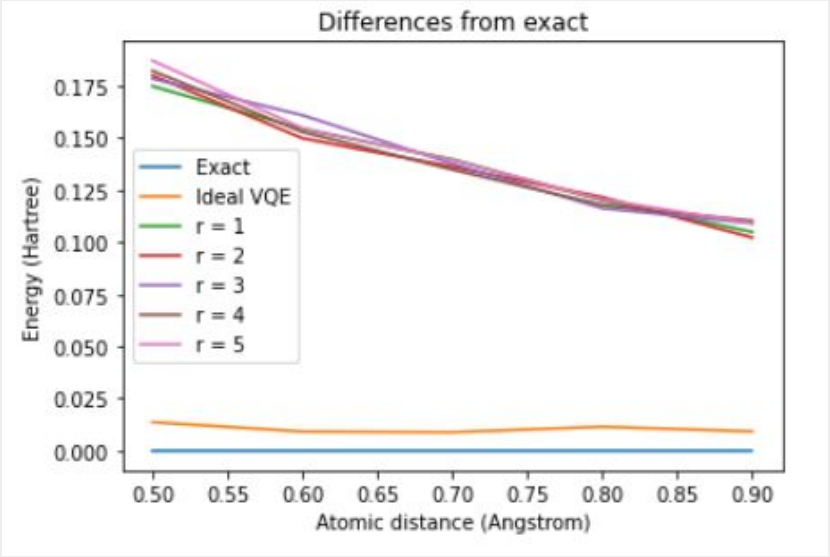
Possible Sources of Error:

1. The ansatz circuit only contains 4 CNOT gates; not enough to produce significant results
2. Not carrying out twirling + error simulation procedure correctly; maybe need to run multiple copies of the same circuit because error simulation is probabilistic.



Expected

(Using simulator with a very simple noise model)



Observed

(Using simulator with noise model of Yorktown machine)

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Questions for Professor Hillery

Classifications of Noise

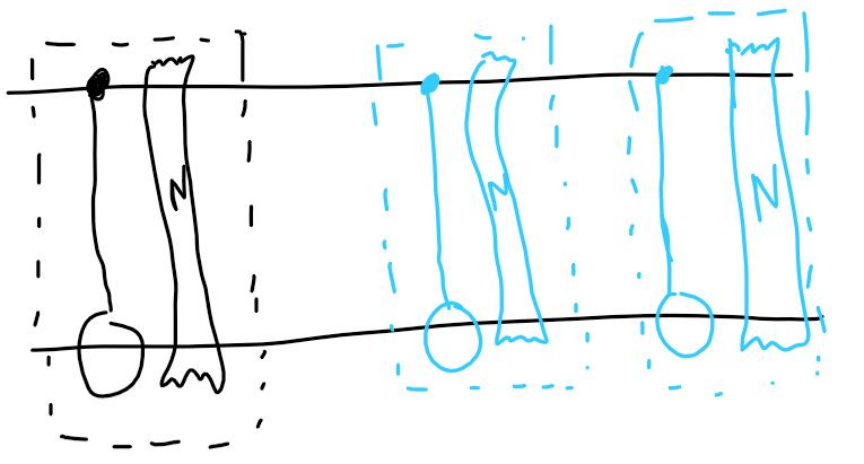
1. What are some examples of non-stochastic noise?
2. How is stochastic / non-stochastic noise different from incoherent/coherent noise?

Noise Amplification:

1. Is the CNOT trick reasonable? *(Slide 9)*
2. Why do we need to twirl all the CNOT gates after applying the above trick to get noise amplified results? *(Slide 10)*

CNOT Trick

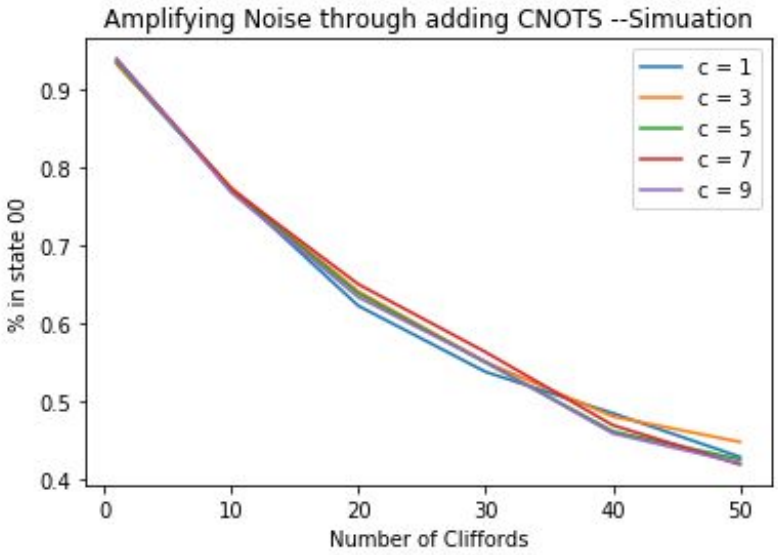
- In order to amplify noise, after each CNOT in a given circuit, we will add **x pairs of CNOT** gates.
- This should amplify noise by a factor of **2x +1**
- If there is no noise in the CNOT gate, then adding a pair of CNOTs is really applying an **identity**; should not change results



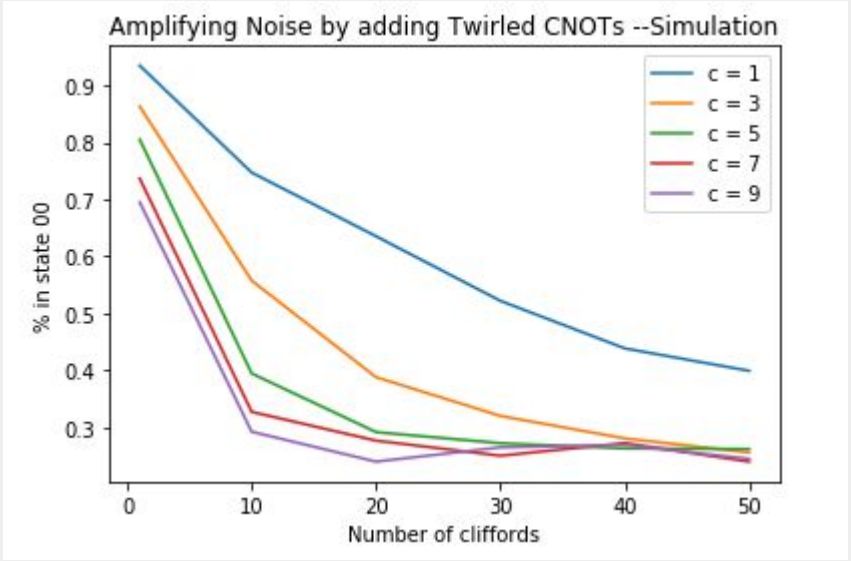
Original Noisy CNOT gate

Adding in a pair of noisy CNOT gates to ***triple*** the noise rate

Decay of qubit states as a function of gate length



Without Twirling



With Twirling

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