**Week 14**

Last week, I looked at how the speed of local quench our system at atom 1 effected the strength and spread of correlations within our system using the correlation function. As expected for faster quench we got strong correlations. Interestingly we noted a greater increase in the speed of the quench was needed in order to increase the strength of correlations at the last atom site vs the first. This is shown in the figure below

This week I will look at linking this behaviour to how the speed of the quench effects the spread and increase of energy in the system. Moreover, I will also look at probing the speed at which correlations travel through our system. In doing so, we note a key difference between classical correlation and quantum entanglement within our measurements, opening questions surrounding the utility of certain measurements.

It feels the direction the project is taking is an analysis of how effective quantum information theory is at describing a non-equilibrium quantum matter system. In a sense, we are looking at cases where we cannot use statistical mechanics to describe the behaviour of the system and are turning to see if concepts in quantum information theory such as entanglement entropy can give insight.

**Looking ahead**

Over the next few weeks I think it would be useful to having a better understanding of what thermalising means in the context of our system and why we don’t see it in our case / to what extent. Then building from this motivate using quantum information theory to describe characteristics of the systems, evaluating to what extent we can reach a ‘clearer picture’.

A very hot topic at the moment is finding way to determine bipartite entanglement in a mixed state, where both classical uncertainty and classical correlations are present (see this:). This divide between entanglement and classical correlation is important to keep track of when considering quantum mutual information and correlation function (I am pretty sure). QMI and the correlation function are not the same as entanglement – but could still be useful is characterising the behaviour of the system. Could also just lead to more confusion.

**Results of the week**

**Energy Spreading**

First, we plot how the speed of the quench effects the expectation energy of the quenched system. We do this for the 3 and 5 atom cases to start with:

Next, we look at how changing the quench speed effects the spread of energies (standard deviation over mean). We plot the 3,5 and 7 atom cases together below. It is apparent that faster quenches seem to spread the energy of the system more. Moreover, as in proportion to the system size a quenching for smaller atom system sizes results in large spreads. It would be interesting to see what we get if we normalise to system size.

These results link nicely to the increase in strength and spread of correlations we saw for faster quenches.

**Propagation Speed**

Next, we will be looking at if there is a way of tracking how fast it takes for the correlations at the quench site 1 to travel to the end of the chain. Is the speed finite? Is linear throughout the chain? Does the speed of the quench effect things?

The way we will probe the speed of entanglement travelling through the system is motivate by this paper: <https://arxiv.org/pdf/2003.10106.pdf>

The idea here is that all atoms will naturally entangle with the rest of the system even without a quench due to the driving laser. However, this entanglement is very minimal compared to the impulse of entanglement we get from a quench. Hence if we are quenching at site 1, we can compare the quench and no quench for atoms at another site as a way of probing the entanglement speed. Below we quench the system at site one for a duration of 0.01 microseconds and measure the von Nuemann entropy between atom 7 and the rest of the system. As we can see, there is a delay between the quench t=0 and the time in which the bulk of the entanglement arrives from the quench.

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Determining we can say the bulk of the entanglement has arrive at site 7 is not clear for this picture. However, we can set a threshold condition for the time in which we can distinguishes the entanglement entropy of the quench versus the evolution of the system itself under interaction. Then we can compare this with the entanglement time

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**Note:** Need to edit axis height on these graphs

**9 atom**

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**QMI**

We will now see if we can do the same analysis with Quantum Mutual information. This difficult thing here is that quantum mutual information measures both quantum and classical correlations.

Question becomes: Is there a speed to classical corelations? Can the QMI tell us a Similar story? Want can we learn for QMI?

**5 Atom**

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