PHSX815_Project3:

A Weird Way to Solve a Real-Life Problem, Part III

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Introduction

In attempt to study population transfer, we introduced interactions between particles as J and the sweeping rate of the external magnetic field as alpha. Here, we take another step forward to make our model, more real-life-like. Our previous model consisted of a number of particles, which could be considered as a chain of particles with different magnetic orders. But here, we suppose that our system consists of multiple chains of particles stacked layer by layer. These arrangement could be interpreted as different layers with opposite magnetic orders, which means that we encounter an antiferromagnetic system. It should be mentioned that our system would be a ferromagnetic material if we consider all layers with similar magnetic orders.

This means that we are able to define a secondary interaction between particles, which defines interlayer interactions. These interactions are defined by J2. Experimental studies show that due to weak van der waals interactions between different layers, J2 could be considered as a ratio of J1. This ratio can vary from 0.1 to 1, which defines the magnetic order strength of our material.

In this study, we have introduced a secondary interaction between particles (J2) in discussed range to study its effect on population transfer. What needs to be mentioned here is that the ratio between J1 and J2 is considered as a function of alpha. This means that the magnetic behavior of the system is a function of alpha, which seems to be a physical impossibility. However, for the sake of study we keep this consideration. In previous studies, we considered a system of three-level systems, where the system's probability of transfer to one of its excited states were studied. But here, we consider a system of two-level system to simulate ferromagnet and antiferromagnets regimes, affected by an external magnetic field.

Fig 1. Chain of 2-level particles

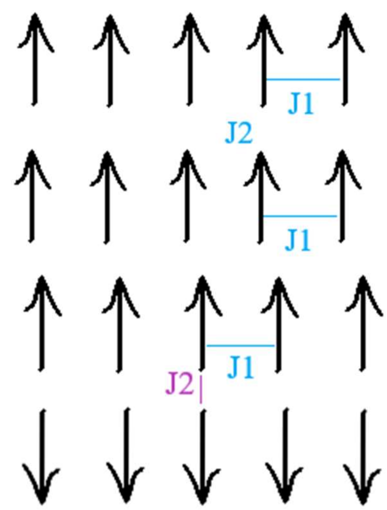

Fig2. (a) Ferromagnet (left) and **(b)** antiferromagnets (right) mediums, studied here. The ratio between J1 and J2 define the strength of the ferromagnetism/antiferromagnetism in our model

Theory and results

Figure 1 represent the initial chain of particles that we started with, while figure 2-a and 2-b represent the system that we attempt to study now. These figures show magnetic orders of stacked particles (ferromagnet and antiferromagnet regimes).

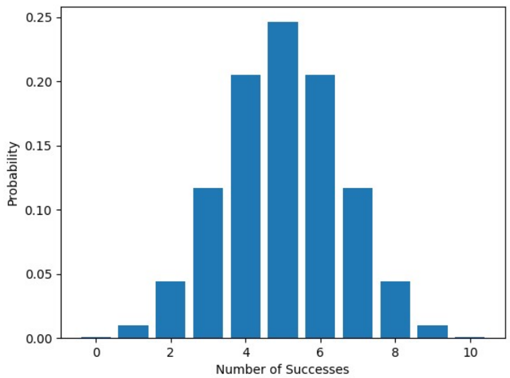

Fig 3. Result of the binomial distribution function code to introduce success rate of the population transfer

As before, an external magnetic field is used to study the population transfer. This study is completed via Landa-Zener model, which you can find in details in projects 1 and 2. Here, we used a simple python code to regenerate the binomial distribution that describes the population transfer. This code can be found in the github folder (named bin.py), which generates a plot that is introduced in fig. 3. This figure tells us about the success rate of the transition for different number of trials.

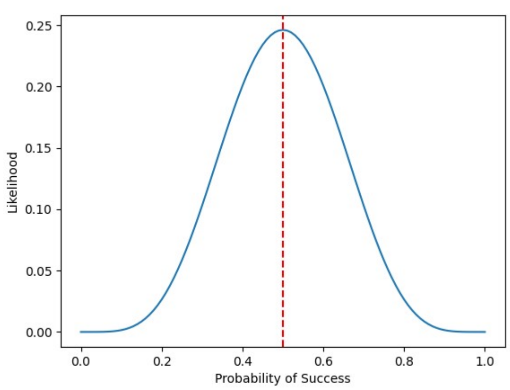

Fig 4. Likelihood of population transfer

In previous studies, we generated a random set of numbers to identify the population transfer probabilities for different states using binomial distribution. As we discussed in previous projects, adjusting the value of alpha can shift the final state of the system between ground or a summation of its excited states.

Figure 4 represents population transfer and the likelihood for a fixed value of alpha. As could be seen here, the probability of finding the correct alpha increases by increasing the number of trials. This code can be found in github as binlike.py.

In the next step, we plot the data for different values of alpha to generate a heat map for no good reason. The result could be seen in figure 5. This graph has nothing to do with what we attempted to study, but I busted my ass to learn how to plot a heat map in python and I thought: hey! I should use it in my paper, so here it is. Please find the code in github folder as likecolbar.py.

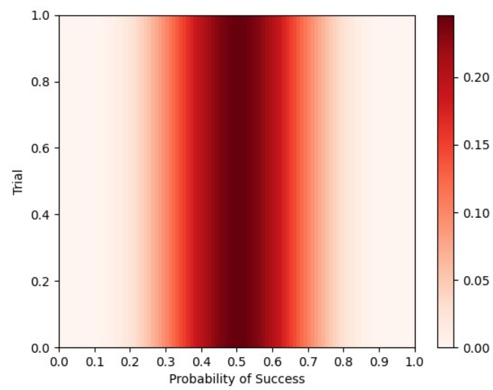

Fig 5: likelihood for different values of alpha in form of a heat map, cause I can.

But certainly, my masterpiece is represented in figure 6, where I plotted likelihood as a function of J1, J2 and alpha. Personally, I didn’t think I could do it after I lost a great number of brain grey cells after doing this task with MATLAB as a master’s student. But all bless goes to Odin, I did the crap out of it.

To do that, I made another binomial distribution and recalled it in my secondary script which you can find in the github folder as J2basedonal.py.

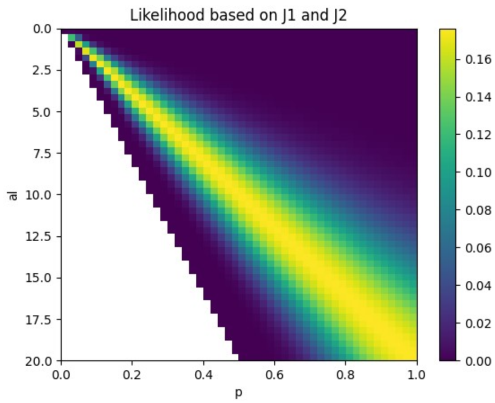

Fig 6. likelihood as a function of J1,J2 and alpha

As could be seen in these figures at low ratios of J2/J1, we encounter that the system is most likely to be found in the ground state. By increasing the ratio between J2 and J1, the system is most likely to be found in one of its excited states. These results are in good company with previous results, which were accomplished using actual simulations, and not with out-of-nowhere random numbers.

Conclusion

As proved in projects 1 and 2, this sort of study adds nothing to our understanding of magnetic order of ferromagnet antiferromagnets systems. to come up with some good results, we need to identify the Hamiltonian of the system, using real values for magnetic field, interactions between particles and other variables. This Hamiltonian needs to be solved using time-dependent Schrodinger equation if we are looking for some meaningful data. But as before, it was fun doing it the wrong way.

References

My endless wisdom.