Lecture 13: Inelastic neutron scattering on quantum hardware
Reading: Chiesa et al, Nat Phys (2019).

1 Introduction

This paper describes how quantum hardware based on superconducting qubits can be used to obtain inelastic scattering spectra of spins on a lattice. The paper is relatively easier to understand than some of the other ones we have looked at, and the circuit required for the calculation is the same correlation function we covered in a recent lecture. Therefore, I refer you directly to the paper for independent reading on this topic.

The essential point that you want to know before reading the paper is that if you derive your scattering cross-section for some particle with non-zero spin, e.g. a neutron, from a lattice of spins using quantum mechanics, analytically carry out Fourier transforms in space and time, you find that what you measure in such an experiment is a spin-spin correlation function of the form:

$$C_{ij}^{\alpha\beta}(t) = \langle s_i^\alpha(t) s_j^\beta \rangle \tag{1.1}$$

where α and β denote Cartesian directions x, y, z and the s_i, s_j are spin operators at lattice sites i and j, respectively. The average (denoted by brackets) is taken to be over a thermal state, or at $T = 0$ as in the paper corresponding to the ground state.

Computing this spin-spin correlation function is classically hard for the same reason as in any other quantum dynamics calculation: the memory required to store the state grows rapidly (often exponentially) with time. Hence, near-term quantum devices may be able to provide these correlation functions in certain instances.