Summary of the thesis

We investigate the two classes of quantum lattice models where relevant questions about the system require analysis of a section of the excited states or the whole spectrum. We study aspects of the description of the Many-Body Localization (MBL) phenomenon and the structure of the low-temperature specific heat of the Kagome antiferromagnet.

MBL is an interesting phase of matter where the disorder-induced systems remain localized even after the introduction of interaction in the system. In an MBL system, states near the edges of the energy band localize first, and with increasing disorder strength, eventually all states become localized. Diagnostic tools such as level spacing ratio statistics, entanglement entropy, return probability, and density imbalance have been extensively studied in the context of MBL. We present a complementary approach, where we study MBL using quantities derived from the single-particle Green's functions. These have analogues in the study of Anderson localization and are, in principle, measurable quantities. We show that these quantities, Local density of states (LDOS) and scattering rates derived from the single-particle Green's functions, provide an alternative way to track the transition from delocalized to MBL phase. We demonstrate this for a whole class of one-dimensional models, starting from short-range to long-range interactions. The ratio of the typical to average LDOS and scattering rates extracted from the single-particle Green's function is of the order of 1 in the delocalized region, and this ratio increases with the system size. In contrast, in the localized region, the ratio becomes vanishingly small and shows no detectable dependence on system size.

The behaviours of the ratio of the two averages in the two phases can be seen to be a result of the difference in the probability distributions of those quantities in the two phases. The log-normal distributions are broad, leading to similar averages in the delocalized phase, but are sharply peaked in a narrow region in the localized phase. We also demonstrate that the single-particle Green's function, when calculated across the entire band, is capable of identifying the many-body mobility edges in an MBL system. Further analysis of the Green's function through finite-size scaling analysis reveals that the critical exponent ν related to the delocalized to MBL transition satisfies the Chayes-Chayes-Fisher-Spencer (CCFS) bound $\nu \geq 2/d$. In contrast, the level spacing ratio statistics violate this bound during the transition.

In the second part of the thesis, we present the results of our ongoing work on spin 1/2 Heisenberg antiferromagnet on a kagome lattice. It is generally expected that the kagome Heisenberg antiferromagnet (KHAF) possesses a quantum spin liquid (QSL) ground state. However, there is no consensus about the nature of the QSL in this system. Our motivation comes from the fact that the low-temperature $(k_b T << J)$ behaviour of the specific heat can reveal the nature of the low-lying excited states in this system. Numerically, we computed the specific heat for systems of up to 36 sites, considering two different geometries and varying strengths of the magnetic field. We find that the presence of a magnetic field can suppress the low-temperature peak and also lead to a reappearance at a higher field. We have verified the field independence of the specific heat at 1K to 4K, within the bounds of experimental error, reported in recent measurements. We provide a detailed description and our current understanding of the data.