Understanding the magnetic interactions of the zig-zag honeycomb lattice: Application to $RuCl_3$

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ABSTRACT:
The new field of Dirac quantum matter has produced a lot of interesting theories and materials, especially in the dynamics of magnetic materials. One such material is $RuCl_3$, which is a S = 1/2 zigzag honeycomb lattice. Through inelastic neutron scattering, this material has demonstrated spin waves with an energy scale of 1.5-8.0 meV. According to literature, $RuCl_3$ may be the realization of a new theoretical phase of matter called a spin liquid. This materials seems to fit the profile and has been investigated using a Kitaev model. In this study, we re-examine the data for $RuCl_3$ using a standard Heisenberg spin-spin exchange model with easy axis anisotropy. By imposing a Holstein-Primakoff expansion and utilizing competing exchange interactions within the zigzag magnetic configurations of $RuCl_3$, we provide insight into the evolution of the spin dynamics. By analyzing the system by adding frustration, we are able to demonstrate that a standard Heisenberg model can produce an accurate model of the observed spin waves is produced. Therefore, with simpler model describing the spin dynamics of $RuCl_3$, we ultimately shed some doubt on the current considerations of $RuCl_3$ as a quantum spin liquid.

MODEL:
Using a Heisenberg spin-spin exchange Hamiltonian, we examine the spin-wave dynamics and excitations for the zig-zag magnetic configuration of the honeycomb lattice. Using a model that incorporates variable nearest neighbor and next-nearest neighbor interactions, we investigate their effects on the overall energy and spin-wave dynamics. Through a comparison of the various model parameters, we find that the observed inelastic neutron scattering excitations in $RuCl_3$ may be a realization of spin frustration with spin-orbit coupling and not necessarily due to the presence of a quantum spin liquid. Future calculation of the spin wave intensities will hopefully clarify this model.

The magnetic interactions of $RuCl_3$ can be described through the frustration of Heisenberg spin exchanges

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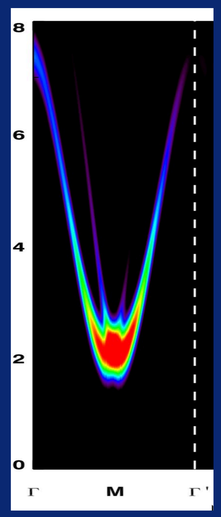
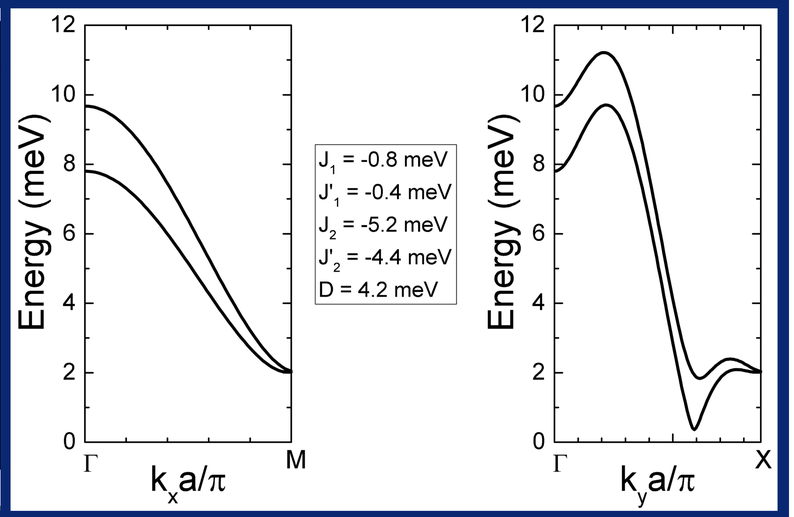
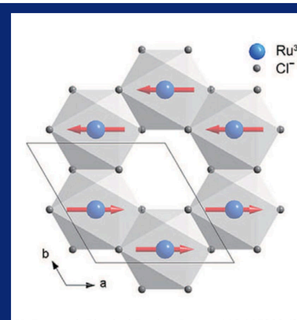
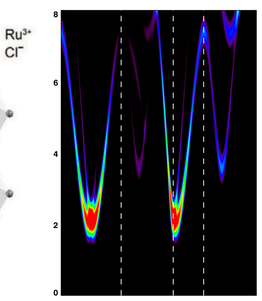
SCAN ME









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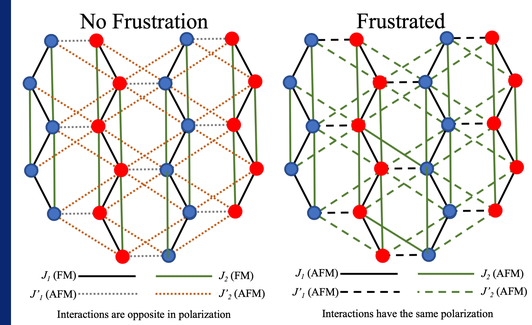
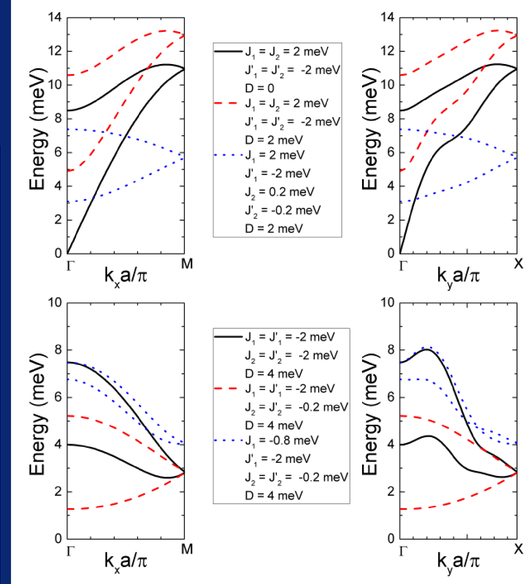


No Frustration Model ↓



Frustration Model ↑