Doctoral presentation: Exact ground state on the 3D analogue of the Shastry-Sutherland model and extension to the maple leaf

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Abstract

Exact results in frustrated quantum many-body systems are rare, especially in dimensions higher than one. The Shastry-Sutherland (SS) model stands out as a rare example of a two-dimensional spin system with an exactly solvable dimer singlet ground state. In this work, we introduce a three-dimensional analogue of the SS lattice, constructed by deforming the pyrochlore lattice to preserve the local SS geometry. Despite the dimensional increase and altered topology, the ground-state phase diagrams of classical Ising and Heisenberg spins, remain analytically tractable and closely follow their 2D counterparts, including the existence of a 1/3 magnetization plateau and umbrella states. For quantum spins S = 1/2, the dimer singlet state survives as an exact ground state over a finite region of the phase diagram. We argue, using exact diagonalization, that the singlet phase is stabilized beyond its 2D counterpart, suggesting enhanced robustness in three dimensions. Despite the three-dimensional connectivity of the lattice, triplets are perfectly localized up to infinite order in perturbation theory. Finally, our approach also applies to the maple leaf, whose dimer singlet ground state for spins S = 1/2 remains an exact solution in 3D. These results offer a rare, controlled platform to explore the impact of dimensionality on quantum frustration and spin dynamics, supported by exact solutions, with the potential for exotic strongly correlated 3D phases.

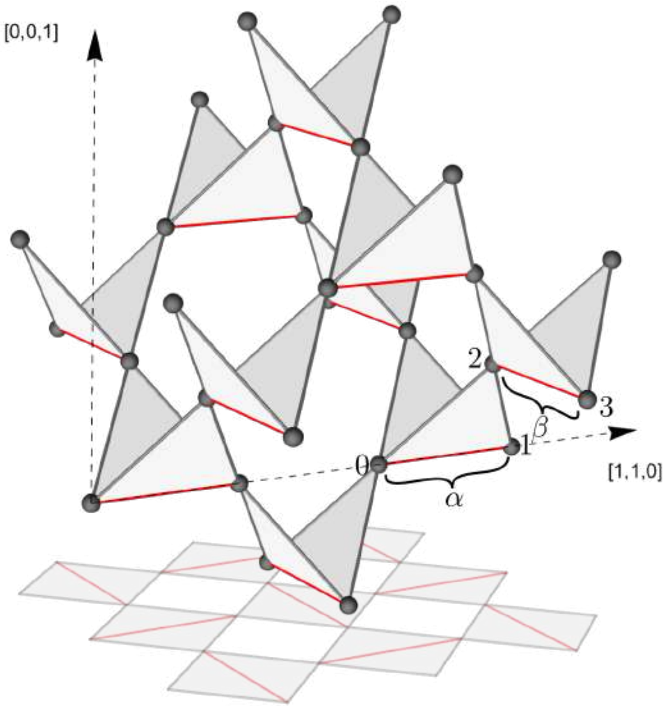

Figure 1: 3D Shastry-Sutherland Lattice