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Quantum Critical Phenomena in an O(4) Fermion Chain

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We construct an interacting spin $\frac{1}{2}$ fermion model with an $O(4)$ symmetry, motivated by the ability to study its physics using the meron cluster algorithm. By adding a strong repulsive Hubbard interaction U, we can transform it into the regular Heisenberg anti-ferromagnet. While we can study our model in any dimension, as a first project we study it in one spatial dimension. We discover that the model is massive and breaks a $\mathbb{Z}_2$ translation symmetry at low temperatures when U is small. Since at large values of U the model is equivalent to a spin-half anti-ferromagnetic chain which is massless for topological reasons, our finding implies that our model has a quantum phase transition from a massive $\mathbb{Z}_2$ broken phase to a topologically massless phase as we increase U. The existence of these two phases is consistent with the Lieb-Schultz-Mattis theorem and our model allows us to study the phase transition between. We present results obtained from our quantum Monte Carlo method near this phase transition.

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